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A NUTRITIONAL KNOWLEDGE SHORT CUT[1]

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Great progress has been made in the identification of the foods of our common game mammals, birds, and fishes during the past decade. A number of palatability studies have contributed information to this phase of food habit studies, but controlled experiments to determine nutritional values of wildlife foods have been comparatively few in number.

Errington (1931, 1933), Maynard *et al.* (1935), and Forbes and Bechdel (1935), were among the pioneers in this field. In 1936 Davenport, of the Michigan Conservation Department, initiated the first extensive nutritional study of white-tailed deer. The paucity of literature on results of studies in wildlife nutrition is amazing and reveals that this phase of food-habit studies is hardly into its swaddling clothes.

One of the limiting factors in wildlife nutritional research has been, and continues to be, lack of adequate funds. Another and related factor is the current belief among wildlife managers and administrators that results applicable to management can be obtained only from direct experiments on the animal involved. This belief is general despite the fact that much of the present knowledge of human and domestic animal nutrition has been obtained through fundamental experiments carried on by biochemists with small laboratory animals, the costs of which are relatively small.

The purpose of the present study was to discover whether certain phases of nutritional problems of white-tailed deer might be solved through the medium of small laboratory animals. It is believed that the results of this study indicate the possibilities of the general method of approach in attacking related problems of other large species at a small fraction of the cost of working directly with wild species. It should be understood however, that this method has certain definite limitations; its greatest importance will be to cut the cost of nutritional studies, by making it possible to reduce the number of the wild species involved to a small number of check animals. The following paragraphs outline the technique followed, discuss the results obtained and list the conclusions drawn as a result of the

[1] Revision of a manuscript originally prepared by the author while doing graduate work in the Division of Wildlife Management, University of Wisconsin in 1938.

feeding experiments with albino rats on white-tailed deer foods.

Initially, an attempt was made to determine the relative nutritional values of some of the medium to highly palatable deer foods which the author (1937, 1938) had previously identified and rated in studies of the white-tailed deer in the Missouri Ozarks. Most of the species collected for study are important white-tailed deer foods in Missouri whose range extends to the Wisconsin deer range; a few species were included which are used as foods in Wisconsin and elsewhere, but whose range does not extend to Missouri. Table 1 lists the species and portions of each selected for study.

TABLE 1.—WHITE-TAILED DEER FOODS COLLECTED FOR STUDY

Common Name	Scientific Name	Portion Collected
American elm	*Ulmus americana*	leaves, shoots and twigs
Black oak	*Quercus velutina*	acorns
Red oak	*Q. borealis*	acorns
White oak	*Q. alba*	leaves, twigs
Gray dogwood	*Cornus racemosa*	shoots
Red-osier dogwood	*C. stolonifera*	leaves, shoots
Shagbark hickory	*Carya ovata*	leaves
Silver maple	*Acer saccharinum*	leaves, shoots
Sugar maple	*A. saccharum*	leaves, twigs
Hazelnut	*Corylus americana*	shoots
Black raspberry	*Rubus occidentalis*	leaves
Goldenrod	*Solidago hispida*	leaves
Staghorn sumac	*Rhus glabra*	leaves, fruit, canes
Wild grape	*Vitis bicolor*	leaves and tendrils

The collections were made in the University of Wisconsin arboretum at Madison during the period October 7–14, 1938. Twigs, fruits and leaves of each species were collected separately in paper bags. They were immediately transported to the laboratory where they were weighed and dried by a forced air draft at 40°–50°C. in a drier previously constructed for drying various tissues to prevent loss of original vitamin content. After being dried the plant tissues were finely ground and stored in moisture-proof containers.

Leaves were collected in late September in the green condition, however, the shoots and twigs were collected the first week in October after the leaves had turned color and begun to fall. Acorns were collected in October and included the husks; sumac fruit included the entire bob. The maximum diameter of twigs and shoots collected was one-fourth inch except sumac which included diameters up to five-sixteenths of an inch.

A routine feed analysis was made on each portion of each plant species collected. This included crude protein, crude fiber, crude fat, ash and nitrogen free extract. A brief discussion of the above terms is desirable to prevent a misinterpretation of these results if reader is not familiar with the terms as used in feed analysis.

Crude protein. The term crude protein is used, since the method of nitrogen determination includes the total or-

ganic nitrogen regardless of source; there are small amounts of nitrogenous compounds present which are not proteins and do not fulfill the physiological functions of proteins when ingested.

Crude fat. This consists of the ether extract of the substance being analyzed and may contain in addition to the glycerides of the fatty acids, appreciable amounts of sterols, pigments, chlorophyll, waxes and other ether-soluble materials which are not fats and do not function as fats in the animal body.

Crude fiber. This is the more resistant woody material remaining after the proteins, fats, and carbohydrates are removed by hydrolysis. It is largely indigestable although the ruminants and the horse can utilize an appreciable amount.

Ash. The ash remaining after the complete oxidation of the plant material does not truly represent the mineral salts in the plant, since many of the salts are changed during the heating process. Organic substances containing sulphur and iodine are destroyed, and a large part of these elements may be lost by volatilization. Ash determination is but a rough index of the mineral content.

Nitrogen-free-extract. After all of the above mentioned constituents have been calculated in percentage of moisture-free plant tissue, the difference between their sum and 100 is the nitrogen free extract. This is composed of carbohydrates, although certain organic acids and similar materials are included.

From the above discussion it is evident that the above terms are not accurate indicators of the nutritive values. Before accurate nutritive values can be assigned foods it is necessary to determine their digestibility coefficients

TABLE 2.—GROSS COMPOSITION OF DEER FOODS STUDIED IN PER CENT

Plant Species	Water	Crude Prot.	Crude Fat	Carbohydrates Crude Fiber	Carbohydrates N-Free Extract	Ash
American elm, leaves	57.15	13.79	7.98	10.25	54.98	13.00
American elm, shoots	46.25	7.58	1.58	42.10	44.29	4.45
Black and red oak, acorns	30.00	6.20	14.49	31.05	45.24	3.02
White oak, leaves	54.55	10.75	4.40	—*	—*	7.90
White oak, twigs	33.10	3.30	1.46	44.10	47.06	4.08
Gray dogwood, shoots	43.90	1.16	1.71	39.80	54.59	2.74
Red-osier dogwood, leaves	64.75	14.45	6.38	—*	—*	10.68
Red-osier dogwood, shoots	51.60	5.66	3.05	57.30	31.12	2.87
Shagbark hickory, leaves	53.20	9.44	7.20	—*	—*	9.30
Silver maple, leaves	56.75	11.68	11.68	—*	—*	9.47
Silver maple, shoots	44.00	2.26	1.65	54.25	33.91	7.90
Sugar maple leaves	38.75	10.42	4.01	—*	—*	13.20
Sugar maple twigs	32.21	4.86	1.05	—*	—*	4.62
Hazelnut, shoots	42.85	6.39	1.35	42.05	41.03	9.18
Black raspberry, leaves	61.70	8.60	5.63	13.02	65.57	7.08
Goldenrod, leaves	65.25	13.80	7.10	10.69	55.91	12.50
Staghorn sumac, leaves	—	6.94	11.07	14.87	59.28	7.84
Staghorn sumac, fruit	7.43	4.97	9.71	37.30	41.31	6.71
Staghorn sumac, canes	47.15	6.27	10.63	33.59	44.69	4.82
Wild grape, leaves	69.40	10.55	6.76			9.35

* Not determined.

from feeding experiments. The results of the analysis of these foods are recorded in Table 2.

Preliminary feeding trials with the finely ground tissues indicated that the albino rat would accept them as food without hesitation and would show a satisfactory weight response in approximately four days. Guinea pigs usually refused each new diet for from three to five days and gave a much slower weight response than rats. All things considered, the albino rat was found to be best adapted as a small laboratory animal for preliminary nutrition studies on deer foods. Those used were males from seven to nine weeks of age. Most of them were sexually mature at the time of the beginning of the feeding experiments.

In all of the feeding experiments the individual foods were placed in separate feeding containers and except for some of the supplemental foods used in the later experiments were in excess of the amount that would be eaten before weighing back to determine the amount consumed. Control rats were placed on a complete ration[2] at the time the feeding experiments were begun. Control rats were of the same age and size as the experimental rats when the feeding experiments were started. During the feeding experiments the animals were confined in an air conditioned room with constant temperature and humidity. All test animals were placed in cages of exactly the same size, all food containers were identical in size and shape; the only known variable during the feeding tests was the food.

The first feeding experiment was conducted on four series of free choice diets, each consisting of four plant species. At the end of four days it was found that each of the four series was deficient, losses in body weights averaged from 18 to 29 per cent. The composition of the diets on this first series and the individual changes in per cent of body weight are given in Table 3.

TABLE 3.—FREE CHOICE DIET 1

Plant Species	Ave. % Loss in Body Wt. in 4 Days
1a	
Shagbark hickory, leaves Red-osier dogwood, leaves Gray dogwood, twigs Silver maple, leaves	28.92
1b	
Smooth sumac, fruit Black raspberry, leaves Goldenrod, leaves White oak, twigs	18.00
1c	
Smooth sumac, canes American elm, leaves American elm, twigs and shoots Red-osier dogwood, twigs	29.05
1d	
Hazelnut, twigs Silver maple, twigs Hard maple, leaves Black and red oak, acorns	28.30

Because of the rapid loss in weight and the low crude protein content of many of the plants in these diets it was suspected that the deficiency consisted mainly of a lack of protein. Therefore in a second series, the diets of the first were supplemented with crude casein in unlimited amounts. Results at the end of four days indicated that our premise may have been correct, since

[2] Composition of complete ration: Yellow corn 71.5%, Butterfat 5.0%, Oil meal 15.0%, $(Ca)_3(PO_4)_2$ 1.0%, Crude casein 5.0%, NaCL 0.5%, Alfalfa meal 2.0%.

changes in body weights now ranged from −3.5 to +11.9 per cent. At the end of an additional four days on this diet the average change in body weight varied from −17.40 to +17.85 per cent, Table 4. During a like period the control rats made an average gain of 16 per cent. It was concluded that diet 1d was deficient in protein and diets 1a, 1b and 1c had other deficiencies in addition to protein.

TABLE 4.—FREE CHOICE DIET 2

Plant Species in:	Ave. % Change in Body Wt.:	
	After 4 days	After 8 days
1a plus crude casein	+ 2.18	− 6.50
1b plus crude casein	− 3.50	−17.40
1c plus crude casein	+11.90	− 2.60
1d plus crude casein	+ 2.05	+17.85

To obtain an indication of the nutritive value of white oak leaves as compared to crude casein which approaches the ideal, white oak leaves were substituted for casein in diet 2d which had produced an increase in body weight of 2.8 per cent in four days. After four days on the diet now consisting of hazelnut twigs, silver maple twigs, hard maple leaves, black & red oak acorns and white oak leaves an average loss of 9.6 per cent indicated that white oak leaves are not equal to crude casein as a source of protein. However, the difference may not be so great as the difference in body weight indicated, since the total food consumption per day per 100 gram rat was only 4.75 grams as compared to 8.24 grams when 1d was supplemented with crude casein. Further confirmation was obtained when rats on white oak leaves as the sole diet lost only 4.12 per cent body weight in four days.

An experiment was conducted as a free-choice diet with twelve plant tissues normally found in the winter white-tailed diet in Missouri, Table 5. A deficiency in this diet was indicated at the end of four days by a 15 per cent loss in body weight. However, the deficiency of this diet was not so great as the first series, Table 3; an indication that a wider variety of winter foods are required to maintain body weight in Missouri than had been previously appreciated.

From the results of the earlier feeding experiments it was suspected that the deficiency was largely due to lack of digestible protein. To check this premise crude casein was added to this diet in an amount equal to 1.7 grams per day per 100 gram rat. At the end of four days the loss in body weight had decreased from 15 to 3 per cent. The amount of crude casein was increased to 2.7 grams per 100 gram rat which reduced the loss of body weight from 3.0 to 2.38 per cent. During the next four days an excess of sucrose was added to the diet in addition to the 2.7 grams of

TABLE 5.—FREE CHOICE DIET 3

Plant Species	Ave. % Change in Body Wt. After 4 Days
Gray dogwood, twigs	
Red-osier dogwood, twigs	
Smooth sumac, fruit	
Smooth sumac, canes	
Silver maple, twigs	
Hard maple, twigs	−15.0
Hazel nut, twigs	
Am. elm, shoots and twigs	
Black and red oak, acorns	
Wild grape, leaves and tendrils	
Golden rod, leaves	
Black raspberry, leaves	

TABLE 6.—RELATIVE NUTRITIVE VALUES OF CERTAIN DEER FOODS, AS INDICATED BY WEIGHT LOSS OF ALBINO RATS

Plant Tissue	Ave. % Weight Loss
White oak, leaves	4.12
Silver maple, twigs	8.40
White oak, twigs	11.85
Goldenrod, leaves	14.32
Black raspberry, leaves	19.10
Sugar maple, twigs	20.50
Red-osier dogwood, twigs	21.20
American elm, leaves	21.65
Black and Red oak, acorns	21.73
Wild grape, leaves	24.40
Staghorn sumac, canes	26.70
Gray dogwood, twigs	27.40
Filter paper and sucrose	29.50
American elm, shoots and twigs	30.35

crude casein, however only 5.97 grams of sucrose were consumed per 100 gram rat per day. The sucrose produced a change in body weight from −2.38 to 6.25 per cent in four days, and during an additional four days remained at 4.62 per cent. No other evidence of dietary deficiency was found during the feeding experiments, however it is possible that other deficiencies will be found when rats are continued on this diet for several months.

In addition to the feeding experiments on the free-choice diets, plant tissues were fed singly during four day periods. The comparative percentage loss in body weight was used as an indicator of their nutritive value. Insoluble carmine dye was administered orally at the beginning and end of each feeding test and the feces resulting from each plant tissue were collected for later determinations of digestibility coefficients. A second series of rats was starved for four days and the average per cent loss of body weight determined. A third series was fed a nitrogen free diet consisting of sucrose and filter paper in a one to one proportion by weight. The relative nutritive values of the plant tissues tested in this manner are listed in Table 6 according to increasing losses of body weight.

By comparing the starvation loss with the loss in per cent of body weight while on each plant tissue it is possible to obtain an indication of how each compares with a diet just able to maintain body weight.

The results listed in Table 7 indicate that these plant tissues vary widely in their ability to combat starvation. Of the tissues tested, white oak leaves were found to have the greatest ability to maintain body weight whereas American elm shoots and twigs were even less able to maintain body weight than sugar. As indicated in detail earlier in this paper, all test animals were placed in exactly similar environments. From the amount of each food eaten and the corresponding per cent of body weight lost on each plant tissue fed, it

TABLE 7.—LOSSES ON SINGLE PLANT TISSUES AS % OF STARVATION LOSS

Plant Species	Palatability Rating*	% of Starvation Loss
White oak, leaves	5	13.3
Silver maple, twigs	9	27.1
White oak, twigs	13	38.2
Goldenrod, leaves	8	46.2
Black raspberry, leaves	7	61.7
Hard maple, twigs	10	66.2
Red-ozier dogwood, twigs	12	68.5
American elm, leaves	2	69.9
Black and Red oak, acorns	1	70.0
Wild grape, leaves and tendrils	6	78.8
Smooth sumac, canes (*R. glabra*)	11	86.2
Gray dogwood, twigs	14	88.5
Cellulose and sucrose	4	88.7
American elm, shoots and twigs	3	97.9

* For white-tailed deer.

was possible to compare palatability with nutritive values. It will be noted from reference to Table 7, that there is no correlation between highly palatable foods and highly nutritious foods. Black and red oak acorns which were most palatable to deer, ranked ninth in nutritive value while oak leaves ranked fifth in palatability and first in nutritive value. The importance of making nutritional ratings of all deer foods in addition to palatability ratings is at once apparent, since it will not be possible to accurately rate their relative values until both have been determined.

There is considerable evidence that the albino rat responds much the same as white-tailed deer when maintained on the same plant tissues. A number of species tested directly on deer by Davenport (1937) were also tested on albino rats by the writer. Oak browse, sugar maple browse, silver maple browse and red-osier dogwood browse produced rapid weight losses when fed to white-tailed deer as the sole diet and similar results were obtained with albino rats. Davenport also found that an unsatisfactory diet composed of balsam fir, white spruce, soft maple and white birch was satisfactory when supplemented with a protein concentrate and the same results were obtained by the writer with albino rats when diet 1d was supplemented with crude casein, Table 4. Feeney's diet No. 4, (1946) Unlimited Mixed Browse, consisting of hard maple, hazel, red-osier dogwood, red maple, mountain maple, basswood, aspen, black ash and hemlock were supposed to have served as a comparatively normal control diet, as representative of the principal food species found in Northern Wisconsin deer yards. He concludes, "The results of the experiment proved that this was a premature supposition, as the deer lost an average of 120% of the allowable loss in 59 days." (This loss corresponds to 24 per cent of body weight.) In comparison, with a free choice diet (Table 5) consisting of twelve plant tissues normally found in the winter white-tailed deer diet in Missouri and including three of the species in Feeney's diet No. 4, a 15 per cent weight loss occurred in four days with albino rats as the test animal.

It is concluded that the limited evidence of similarity or results, quoted above, is not sufficient to establish that results obtained with albino rats on deer foods will be duplications of results obtained with the same foods on deer; the results do indicate however, that the technique developed, tested and presented is reliable for making a rapid nutritional comparison of deer foods, the cost of which is infinitesimal when compared to the cost of making a nutritional comparison of deer food by deer alone.

DISCUSSION

It will be evident by comparing the ability of each plant species to combat starvation (Table 7) with its gross composition (Table 2) that a routine feed analysis is not a reliable indicator of the nutritive value of a deer food. Therefore a rapid biological assay method is much to be desired and this has been found to be available through the medium of the albino rat.

In addition to demonstrating that certain phases of white-tailed deer nutritional problems may be solved in this manner, the study also demonstrated that variables such as tempera-

ture, humidity and light can be eliminated so that the only variable is the diet under test. Similar controls have not been used in the deer feeding experiments to date because of the prohibitive costs. Another advantage of this method of approach is speed in obtaining results. Results are obtained in 4 days, with but few exceptions in which results are obtained in 8 days or less. In Feeney's work with white-tailed deer (1946), from 23 to 68 days were required; the average being 54 days to obtain results on one diet. Comparable time was required in the experiments carried on by other workers in similar nutritional studies with deer. When it is realized that an average of 54 days and from 40 to 70 deer are required to test 14 diets, the relative time and cost factors of albino rat *vs.* deer assume great significance. The importance of the time and cost factor will be even more evident when it is realized that more than 600 white-tailed deer foods had been reported by the author in 1941 and additional papers by others have added materially to this number since that time. The fact that most deer management problems are attacked on a state-wide, or smaller, unit basis would limit the study to the deer foods of the area in question, but these might well exceed 200 (Atwood, 1938). Therefore, on the basis of current progress with deer as the primary experimental animal, as reported by Davenport (1937) and Feeney (1946), a conservative estimate of the time required to rate the foods in the average state-wide range would be 10 years. As compared to this, one capable man using not over 60 rats could make a survey of 200 deer foods, as single food item diets, in from four to five months. The advantage of the latter method in preliminary nutrition studies of deer is obvious. It is also apparent that the use of rats in nutritional studies of deer would reduce the cost of the project tremendously, since the number of experimental deer could be reduced to the number required only for spot check tests.

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THE INFLUENCE OF CLIMATE ON THE RING-NECKED PHEASANT

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Of all the exotic animals that have been introduced into the United States the ring-necked pheasant has probably been released in the greatest variety of habitats. From the Atlantic to the Pacific, and from Canada to the Mexican border releases of this magnificent bird have been made in almost every state. In the northern tier of states, wherever favorable farm practices prevail and where winter snows are not too deep, the species has been successful in establishing and maintaining successful populations. This has been especially true in the northeastern parts of the great plains where almost unbelievable numbers occur in favorable years. Toward the south, successful establishment has been less frequent, and in the states of the far south failure has invariably followed liberations.

Numerous hypotheses have been suggested to explain the peculiarities of pheasant distribution. Leopold proposed the glacial hypothesis. It has been thought by many that an abundance of lime in the soil may be essential to success of the pheasant. Others have looked for an explanation in food limitations, availability of grit, the effects of ice, excessive precipitation, and various other factors. Exceptions can always be found to contradict any hypothesis thus far proposed. Probably no one limiting factor can account for all of the peculiarities of pheasant distribution in the United States, but there must be some important condition that will explain the uniform failure of pheasants toward the south.

Because the ring-necked occurs naturally throughout a wide range of climatic conditions in its native land, there has been a tendency to assume that climatic limitations were of minor importance. The pheasant endures winter temperatures far below zero Fahrenheit and summer temperature close to 100° in some of the northern states where it has been successful. It has succeeded in widely divergent climates as that of the Dakotas, and parts of the Hawaiian Islands. Certainly no line marking the limits of ring-necked distribution could be drawn on the basis of either annual mean, maximum, or minimum temperature, or summer or winter temperature. Neither can the average picture of precipitation in a locality give any obvious hint that the bird would be either a success or a failure in a given place.

Nevertheless when the range of the pheasant in the north Central States is examined, it becomes evident that toward the south the pheasant population dwindles and finally disappears. This certainly suggests that some climatic effect is operating. How it is operating is not apparent at first glance. Perhaps, however, a more detailed examination of climatic factors in different localities might bring out similarities and differences otherwise overlooked.

With this in mind, climatographs of a

series of localities where the ring-necked has been successful were compared with another series where the birds have been unsuccessful or only partly successful. There seemed to be no consistent similarity in the form of the graphs representing successful localities (Figure 1). For instance, Portland, Oregon has wet, mild winters and dry, moderately warm summers; the Dakotas, in contrast, have cold, relatively dry winters, and hot relatively dry summers. In general, however, the pheasant has been successful most often in localities with cold or cool dry winters and warm summers with moderate rainfall. Nevertheless, the exceptions to this rule are not infrequent; the obvious conclusion being that in the United States, as in Asia, the pheasant succeeds under a considerable variety of conditions. But more detailed examination of the climatographs reveals an interesting point hitherto overlooked. One segment of all the graphs of localities where the birds have been successful fall in the same area. Between the first of April and the first of June and birds experienced similar conditions in all successful localities studied. On the contrary, the climatographs for unsuccessful localities fall in a different area during the same period (Figure 2.)

This graphic picture suggests a situation wherein the animal can endure wide extremes of meteorological conditions through most of the year, but may be definitely restricted by them during one season. Similar observations on certain insects led Uvarov (1932) to conclude that in evaluating the effects of any physical factors upon an animal, each stage in the life cycle of the organism must be considered separately. In comparing climatographs he suggested that rectangles enclosing the period for each stage be superimposed on the usual climatograph. Horizontal and vertical lines were drawn through the early and late dates for each stage, their points of intersection forming the corners of a series of overlapping rectangles on the climatograph. The resultant figure he called a "bioclimatograph."

Applying this method to the pheasant problem we find that the period when the corresponding parts of all the favorable climatographs fall within the same area on the graph is between April 1 and June 1, the period when the peak of oviposition occurs. The similar segments of the unfavorable climatographs either fall outside the area enclosed by the favorable rectangle or barely enter it (Figure 2). From this it may be concluded that if the distribution of pheasants is limited in any way by temperature or precipitation the effects must be during the spring season.

The adult birds obviously are able to endure wide variations of temperature and rainfall. Therefore, any direct effects on them during the spring seems improbable. Whatever the effects may be, the climatographs indicate that they manifest themselves prior to hatching of the pheasants, because that event extends through June into July. During incubation the eggs, except for brief periods, are protected by the setting hen, and are maintained within a restricted range of temperature. Except for possible flooding they are not exposed to the effects of precipitation during incubation. Therefore, any general limitations on southern extension of the pheasant range by either temperature

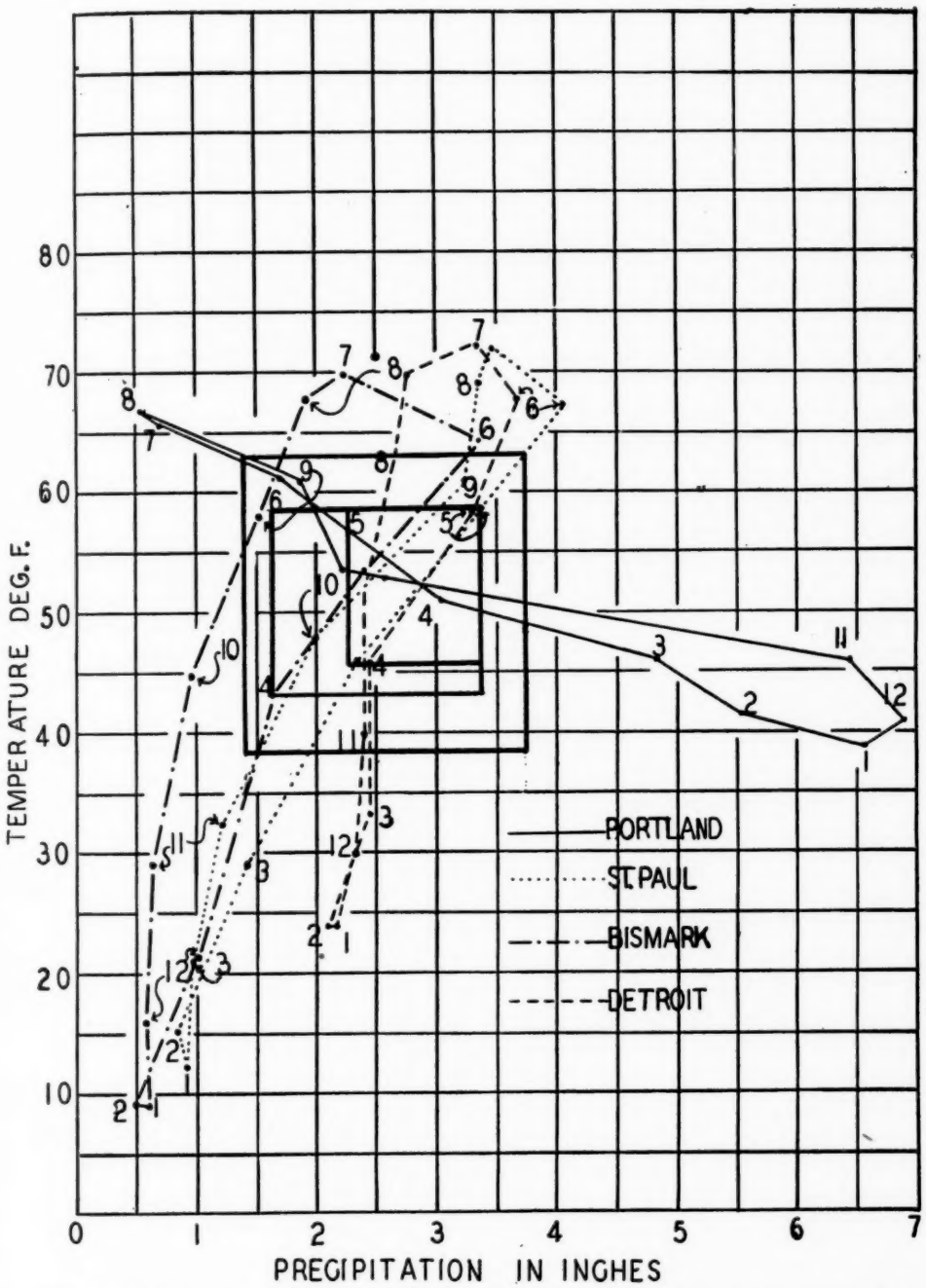

FIG. 1.—Climatographs for four diverse localities where pheasants have been successful in the United States. Numbers indicate months of the year. The largest superimposed rectangle encloses all combinations of temperature and precipitation that occur on the average between mid-March and mid-June. The middle rectangle encloses all combinations for April and May. The smallest omits the April point for Bismark, where conditions are especially cool and dry at that time, and early nesting is therefore somewhat retarded, and represents conditions that characterize successful pheasant range during the peak of oviposition.

or precipitation should not be looked for during the period of incubation but rather in the egg laying period. The limiting factor could not obviously disturb a nest, otherwise renesting would counteract the effect. Any effect that would kill the eggs without disturbing the hen would satisfy the requirements.

We know that pheasants usually select grass or sedge cover for their nests. During oviposition the hen visits the nest only for the brief periods required to deposit eggs. At other times the eggs are exposed to direct solar radiation unless, by chance, they happen to be placed in an unusual, shady spot. It is well known that ground temperatures in the sun are sometimes very high, 150°F. having been observed in midsummer, and that the temperature reached depends not only on the clearness of the atmosphere and air temperature, but also upon the angle of incidence of the sun's rays. Therefore, from north toward the south the sun's rays at noon would be closer and closer to the vertical and therefore would pass through the atmosphere for a shorter and shorter distance. Other things being equal, the surface temperature would be progressively higher. It is also known that a temperature of 113°F. or even less continued for several hours is fatal to most forms of animal life, and it is safe to assume that pheasant eggs would be no exception.

At this point the argument departs from the factual and enters the hypothetical. North of a certain line, because of the greater angle of incidence of the sun's rays, surface temperature would remain below a point fatal to eggs lying in direct sunlight during the period of oviposition. South of that line fatal temperatures would prevail on clear days and would prevent successful establishment of the birds. Seasonal differences would result in temporary shifts in the position of this line, accounting for temporary successes toward the south. Thus there would be a belt in which the birds would nest successfully in some years, but not in others, and the pheasant would persist, but would never attain a high population.

Furthermore, the line limiting southern distribution would not run due east and west, but would vary according to elevation, local effects of soil, proximity to bodies of water, soil moisture, and other modifying conditions.

This hypothesis seems to fit the known facts in the United States rather well. It should be remembered, however, that ring-necked pheasants have been successful in tropical localities, where the intensity of insolation is higher than in southern Ohio, Indiana, or Illinois where pheasants have failed. This may be explained when it is remembered that the birds have been successful only in the moist tropics characterized by lush vegetation the year around. Therefore, in the absence of direct evidence, it seems reasonable to expect that in the tropics, vegetation would shade the nests, and protect the eggs from excessive isolation. In the United States vegetation is always sparse on grasslands in the spring, because the grasses practically all die back in the winter.

From this discussion of meteorological influences it seems entirely possible that the southern distribution of pheasants in the United States may be due to intense spring insolation of the exposed

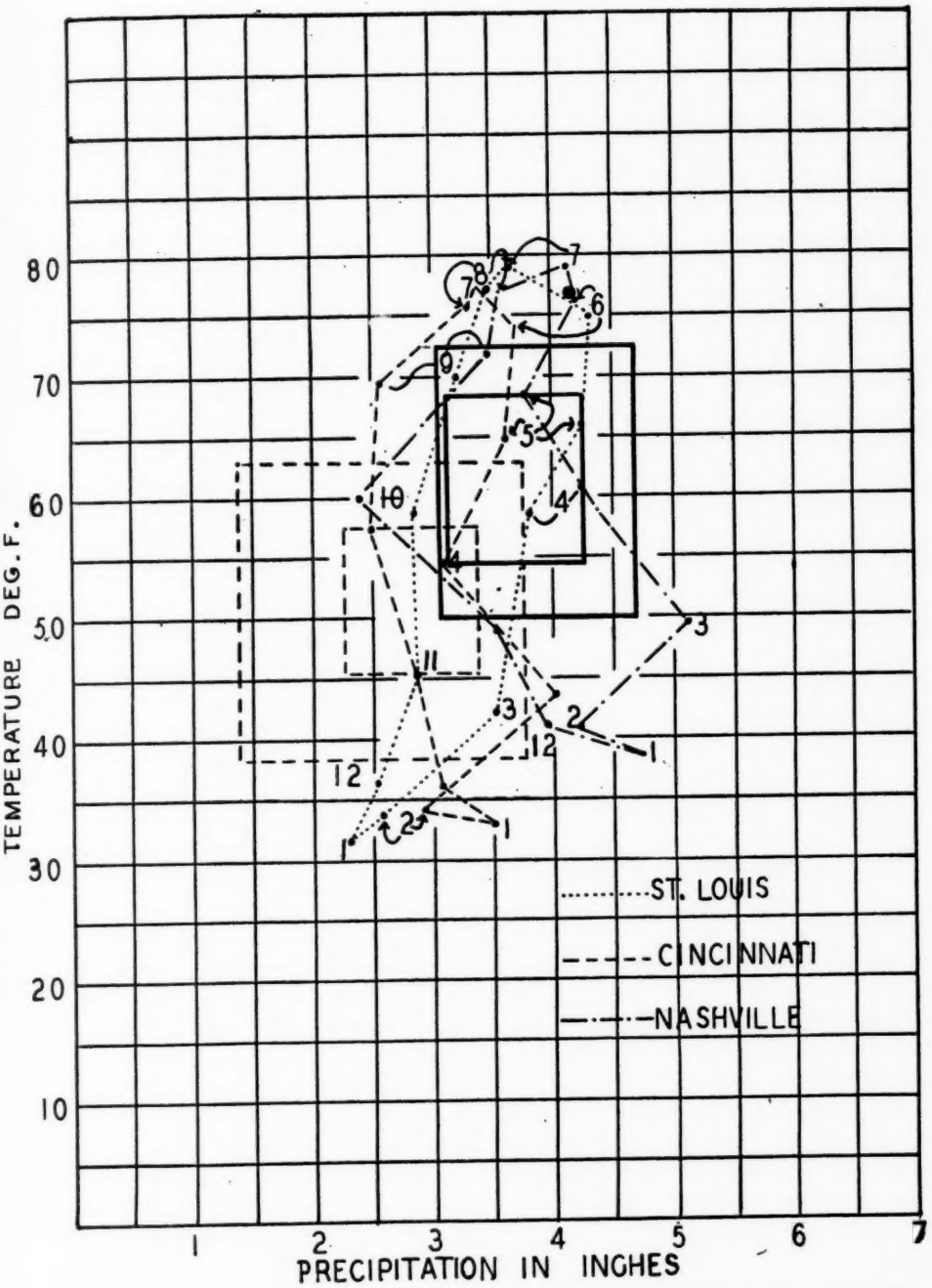

FIG. 2.—Climatographs of three localities south of the successful pheasant range. Rectangles indicated by broken lines are transferred from Figure 1, and represent conditions from mid-March to mid-June, and at the peak of oviposition for the favorable areas. The rectangles drawn in solid lines enclose the same periods for the unfavorable localities. A slight overlapping occurs in April, but May is both wetter and warmer than in the successful areas. The numbers indicate months of the year.

eggs during oviposition. However, it must not be inferred that temperature is the only controlling factor. If the insolation hypothesis, here postulated, proves to be sound, spring and early summer temperatures on exposed surfaces would mark the limits of possible distribution toward the south. But within the favorable area other limiting factors would operate to make specific localities either favorable or unfavorable.

Testing an hypothesis of this sort usually cannot be done by any one individual or group. Data are not easy to collect. Before it can either be accepted or rejected, pheasant nests killed by radiation must be observed, temperature records at the ground surface and inside eggs must be accumulated in many localities and under a variety of conditions. But because it fits the known facts, it warrants careful consideration. Therefore, this paper has been prepared to present the hypothesis and not to defend it. Workers on the southern fringe of pheasant distribution are in a favorable position to test its adequacy.

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REFERENCE TABLES FOR DATING EVENTS IN NESTING OF RING-NECKED PHEASANT, BOBWHITE QUAIL, AND HUNGARIAN PARTRIDGE BY AGING OF BROODS

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The tables presented in this paper were constructed to facilitate assembling of local data on the nesting phenology of the ring-necked pheasant, the bobwhite quail, and the Hungarian partridge from brood studies. They are based on the method of aging juveniles by examination of the molt stage of the juvenile primaries as described by Buss (1946) for pheasants, by Petrides and Nestler (1943) for quail, and by McCabe and Hawkins (1946) for Hungarian partridge.

The post-juvenile molt of the primaries begins at four weeks of age in the three species and the rate is relatively uniform, each stage representing a definite age of chick. When the age is known, the date of laying of the first egg, the date on which incubation began, the date of hatching, and the date of "maturity" can be determined for the brood from which the collection was made. "Maturity" is considered to be reached in two weeks following the last molt stage, as the birds are then beyond the "squealer" stage and have practically reached maximum first year

weight. These tables provide a reference for the rapid determination of these dates.

With experience the field worker acquires the ability to approximate closely the age of chicks by general appearance so that chicks need not be collected for molt examination from all broods. A comparison, using pheasants, of the estimating method applied before collecting with the primary molt stage technique applied after collecting showed a maximum difference of one week.

The primaries are the outer flight feathers of the wing arising from the "hand" and are to be distinguished from the secondaries, which arise from the "forearm." The primaries are numbered consecutively from one to 10, commencing with the innermost (Figure 1). This numbering follows the sequence in which they are molted, the outer primaries being shed and replaced last. Quail and Hungarian partridges molt only through primary eight in their first fall, so the respective tables stop at this point. In determining the number of the latest-shed primary, which is indicated by a gap or a growing replacement blue at the base, it is usually safer to count backwards from 10, the outermost primary, as confusion sometimes arises as to where the secondaries end and the primaries begin. Counting both ways give a double check.

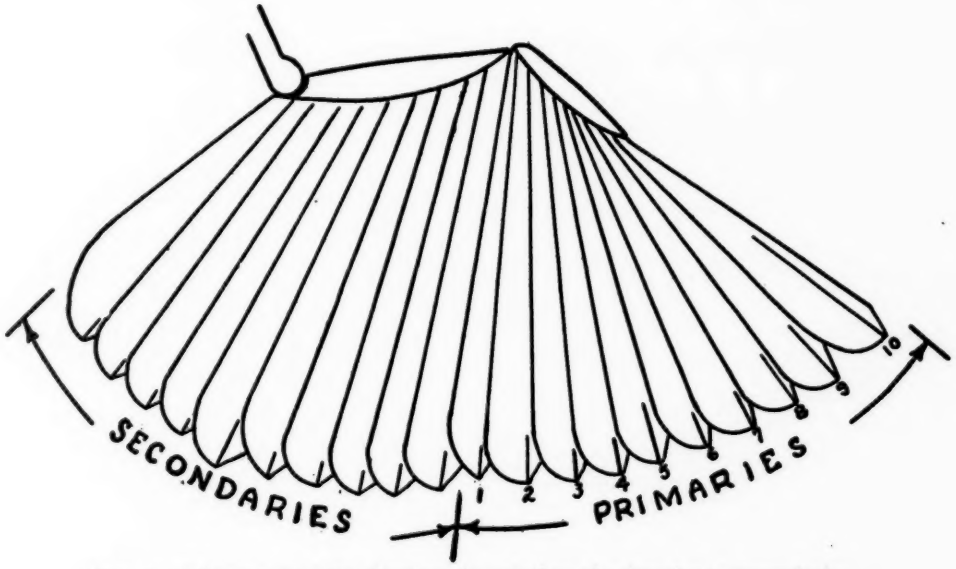

FIG. 1.—Diagram of wing showing the relation of primaries to secondaries.

The use of the tables can best be described by an example. On the 20th of July a pheasant chick is examined; primary four has been molted and regrowth of the replacement has not begun (Figure 2). Using the pheasant table, we look under the column headed

TABLE 1.—RING-NECKED PHEASANT

| Age | | |

the primaries as an indicator of age as described above is not new, but it needs critical delineation. It is probably subject to slight variation from minor causes, such as genetic, latitudinal, and climatic factors.

Variation in hatching date appears to be of small consequence in rate of molt of primaries. Buss (*op. cit.*) examined three groups of known-age pheasant chicks being raised by sportsmen and listed the primary molt condition of these birds. A statistical evaluation of his results shows a chi-square value of 0.39 when one week plus or minus is used as the tolerance limit. This indicates very high correlation of primary molt stage with age in game farm pheasants of different hatching dates.

The data presented by Petrides and Nestler on captive quail (*op. cit.*) does not lend itself to an exact test of correlation of primary molt with age, inasmuch as only the maximum deviations are given. The maximum deviation found among all age groups was 13 days in a group of 20 birds which were 98 days old. The standard deviation would of course, be much smaller. Fall sampling of the same coveys of quail at in-

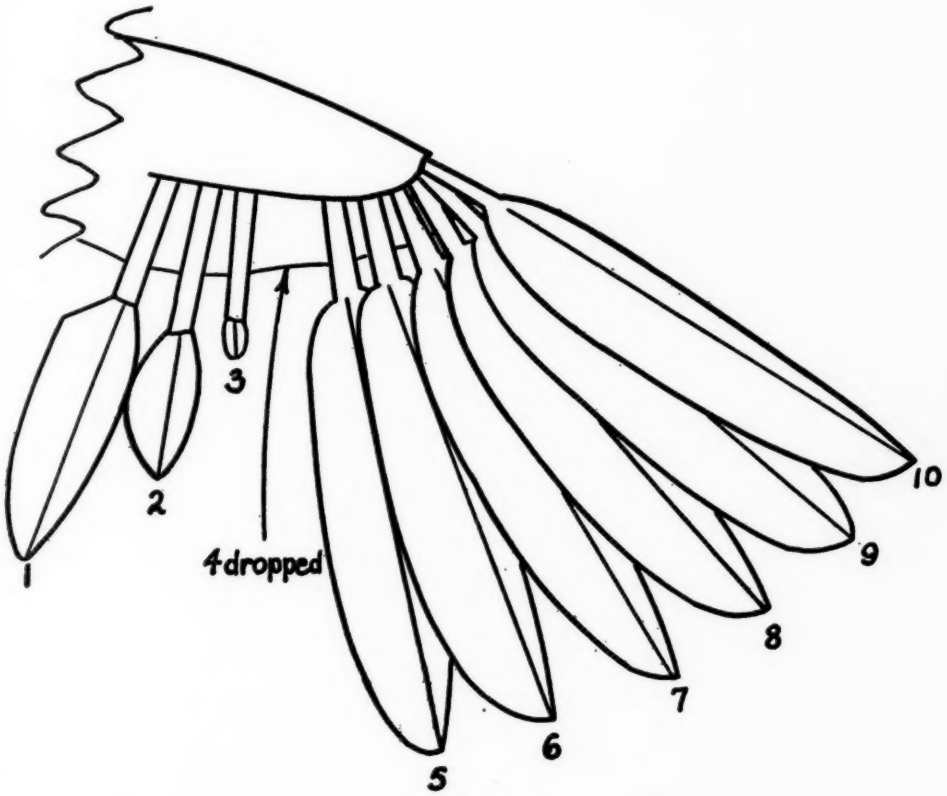

FIG. 2.—Diagram of molt of primaries in which #4 is the latest-shed primary (corresponding to pheasant chick of 6½ weeks age, and bobwhite and Hungarian partridge chicks of 7 weeks age).

TABLE 2.—BOBWHITE

Age			4 wks.	5 wks.	6 wks.	7 wks.	8 wks.	9 wks.	10½ wks.	14½ wks.	16½ wks.				
Primary Dropped			1	2	3	4	5	6	7	8	Mature				
Date of 1st Egg	1st Day Incub.	Date of Hatch.										Age at Hunting Season Opening on Nov. 2	Nov. 23	Nov. 30	
Apr. 5	Apr. 22	May 16	June 13	June 20	June 27	July 4	July 11	July 18	July 29	Aug. 26	Sept. 9	170	191	198	Mature
12	29	23	20	27	July 4	11	18	25	Aug. 5	Sept. 2	16	163	184	191	
19	May 6	30	27	July 4	11	18	25	Aug. 1	12	9	23	156	177	184	
26	13	June 6	July 4	11	18	25	Aug. 1	8	19	16	30	149	170	177	
May 3	20	13	11	18	25	Aug. 1	8	15	26	23	Oct. 7	142	163	170	
10	27	20	18	25	Aug. 1	8	15	22	Sept. 2	30	14	135	156	163	
17	June 3	27	25	Aug. 1	8	15	22	29	9	Oct. 7	21	128	149	156	
24	10	July 4	Aug. 1	8	15	22	29	Sept. 5	16	14	28	121	142	149	
31	17	11	8	15	22	29	Sept. 5	12	23	21	Nov. 4	114	135	142	
June 7	24	18	15	22	29	Sept. 5	12	19	30	28	11	107	128	135	
14	July 1	25	22	29	Sept. 5	12	19	26	Oct. 7	Nov. 4	18	100	121	128	
21	8	Aug. 1	29	Sept. 5	12	19	26	Oct. 3	14	11	25	93	114	121	Immature
28	15	8	Sept. 5	12	19	26	Oct. 3	10	21	18	Dec. 2	86	107	114	
July 5	22	15	12	19	26	Oct. 3	10	17	28	25	9	79	100	107	
12	29	22	19	26	Oct. 3	10	17	24	Nov. 4	Dec. 2	16	72	93	100	
19	Aug. 5	29	26	Oct. 3	10	17	24	31	11	9	23	65	86	93	
26	12	Sept. 5	Oct. 3	10	17	24	31	Nov. 7	18	16	30	58	79	86	
Aug. 2	19	12	10	17	24	31	Nov. 7	14	25	23		51	72	79	
9	26	19	17	24	31	Nov. 7	14	21	Dec. 2	May not complete moult.		44	65	72	
16	Sept. 2	26	24	31	Nov. 7	14	21	28	9			37	58	65	

TABLE 3.—HUNGARIAN PARTRIDGE

Age			4 wks.	5 wks.	6 wks.	7 wks.	8 wks.	9 wks.	11 wks.	13 wks.	15 wks.				
Primary Dropped			1	2	3	4	5	6	7	8	Mature				
Date of 1st Egg	1st Day Incub.	Date of Hatch										Age at Hunting Season Opening on Oct. 12	Oct. 26	Nov. 9	
Apr. 1	Apr. 20	May 15	June 13	June 20	June 27	July 4	July 11	July 18	Aug. 1	Aug. 15	Aug. 29	149	163	177	Mature
8	27	22	20	27	July 4	11	18	25	8	22	Sept. 5	142	156	170	
15	May 4	29	27	July 4	11	18	25	Aug. 1	15	29	12	135	149	163	
22	11	June 6	July 4	11	18	25	Aug. 1	8	22	Sept. 5	19	128	142	156	
29	18	13	11	18	25	Aug. 1	8	15	29	12	26	121	135	149	
May 6	25	20	18	25	Aug. 1	8	15	22	Sept. 5	19	Oct. 3	114	128	142	
13	June 2	27	25	Aug. 1	8	15	22	29	12	26	10	107	121	135	
20	9	July 4	Aug. 1	8	15	22	29	Sept. 5	19	Oct. 3	17	100	114	128	
27	16	11	8	15	22	29	Sept. 5	12	26	10	24	93	107	121	
June 4	23	18	15	22	29	Sept. 5	12	19	Oct. 3	17	31	86	100	114	Immature
11	30	25	22	29	Sept. 5	12	19	26	10	24	Nov. 7	79	93	107	
18	July 7	Aug. 1	29	Sept. 5	12	19	26	Oct. 3	17	31	14	72	86	100	
25	14	8	Sept. 5	12	19	26	Oct. 3	10	24	Nov. 7	21	65	79	93	
July 2	21	15	12	19	26	Oct. 3	10	17	31	14	28	58	72	86	
9	28	22	19	26	Oct. 3	10	17	24	Nov. 7	21	Dec. 5	51	65	79	
16	Aug. 4	29	26	Oct. 3	10	17	24	31	14	28	12	44	58	72	
23	11	Sept. 5	Oct. 3	10	17	24	31	Nov. 7	21	Dec. 5	19	37	51	65	
30	18	12	10	17	24	31	Nov. 7	14	28	12	26	30	44	58	

tervals by Kabat in 1946 and the senior author in 1947 (unpublished) in Dane County, Wisconsin, showed that progression of molt of primaries corresponded closely to increasing age. McCabe (verbal communication) states that practically no variation existed in the Hungarian partridge chicks from which he gathered his molting rate data.

The technique herein described was applied to wild pheasants on the University Bay area at Madison. Pheasant brood observations were made at irregular intervals throughout the summer and fall of 1946. Observations on two different days are here compared, the days used being selected on the basis of bulk of observations and calendar interval. On July 13, thirty chicks from six broods were aged by sight and collecting. The average age of these chicks was determined to be 5.2 weeks, with a standard error of ± 0.3 weeks. On August 27, which is 6.4 weeks later, forty-five similar observations on eighteen broods were made. Here the average age was determined to be 11.6 weeks, ± 0.3 weeks. Thus it is seen that the calendar difference in age (6.4 weeks) agrees exactly with the difference in estimated age ($11.6 - 5.2 = 6.4$). The peak of hatching is thus shown to have been about June 7. Such high correspondence of observations is not as a rule to be expected, but this case serves to demonstrate that the technique can be successfully applied to wild birds.

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PHEASANT DATA FROM A TWO-YEAR BAG STUDY IN SOUTH DAKOTA[1]

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During the 1945 and 1946 hunting seasons over 14,000 ring-necked pheasants were examined to obtain age ratios, weights and other data. Most of the birds were checked at locker plants in towns throughout the pheasant range, taking the birds as they came to secure a representative sample. Because hunters frequently traveled considerable distances from the towns in which they stayed, the birds at the locker plants usually came from a number of counties. Thus the data for any one county are modified to some extent by data from birds killed outside the county but brought into it for storage. Differences between counties tend to become averaged out but are not obscured.

Age Ratios

The age ratio or number of young per adult is the most significant figure to come from the bag checks since it is an accurate index to nesting success and juvenile survival up to the hunting season.

In this study, ages of cocks were determined by spur lengths, using the Kimball age gauge (Kimball, 1944) and ages of hens were determined by examination of the bursa of Fabricius. Since describing the age gauge in 1944, Kimball has improved its accuracy by increasing the hole diameter to 25/32." A bushing washer of this size is made into a gauge by cutting an opening in one side.

Table 1 shows the age ratios for the 1945 and 1946 seasons.

These age ratios indicate very poor reproduction for both years. With an almost equal sex ratio, as exists in South Dakota, the reproduction necessary to maintain a constant population would yield a fall age ratio of almost 3 young per adult. The age ratio for 1945 was only one-third of this, and that for 1946 only one-half. As a result, the decline in numbers of pheasants which was serious, though not apparent, in 1945, continued in 1946, and was reflected in noticeably poor hunting. From the age ratio figures available it would appear that South Dakota's pheasant population may have been cut in half in 1945 and reduced by one-third in 1946 through poor reproduction and/or high juvenile mortality.

Reproductive success in 1946 varied in different parts of the pheasant range. (The pheasant range includes roughly the eastern half of the State.) A group of seven east-central counties had the poorest reproduction with an age ratio

[1] Contribution from Pittman-Robertson Wildlife Research Project 17-R, South Dakota Department of Game, Fish and Parks. Data for this study were collected by Game Technicians Harry Woodward, Arthur Dodds, Reuel Janson, H. R. Huff, Winston Banko, Carl Trautman and Clarence Williamson. State Game Wardens assisted in the study in 1946. James W. Kimball, project leader, assisted with field work and gave advice and criticism in preparation of the manuscript.

of 1.18. Best reproduction was found in the southern part of the range where for 16 counties the average age ratio was 2.00, and in five northeastern counties where the ratio was 2.39. In the northwestern part of the range, the age ratio varied from high to low in a group of seven counties and averaged 1.28.

24, 1946 the age ratio of all birds was 1.64 young per adult, while from October 25 to November 5, 1946 it was 1.22, a decrease of 26 per cent. Young birds are probably less cautious early in the season and are shot in higher proportion to adults than they actually exist in the population.

TABLE 1.—AGE RATIOS OF PHEASANTS

Date	Cocks		Hens		Total	
	Number	Yg/Ad	Number	Yg/Ad	Number	Yg/Ad
Sept. 29 to Dec. 20, 1945	3,759	1.09	723	0.91	4,482	1.06
Oct. 15 to Dec. 13, 1946	4,880	1.51	2,016*	1.57	6,896	1.53

* For period Oct. 15 to Nov. 18. Hens were protected after this date.

These age ratios correspond with and confirm the pattern of reproductive success shown by brood counts and census data from the summer work. Compared with 1945, the pattern was very similar, except that the area of best reproduction in 1946 included a larger portion of the southern part of the range.

The age ratio decreased as the season progressed, more young per adult being killed in the first 10 days of the season than in the second. Data from counties where checks were made in both periods show that from October 15 to October

TABLE 2.—SEX COMPOSITION OF HUNTERS' BAGS, 1946

Period	Number of Birds	Sex Ratio
		♂ ♀
Oct. 15–24	5,140	220:100
Oct. 25–Nov. 5	3,003	178:100
Nov. 6–12	947	122:100
Nov. 13–18	564	238:100

SEX COMPOSITION OF THE KILL, 1946

In the best pheasant range, from one to two hens were allowed in the daily bag until November 18 when a ban on hen shooting went into effect. The sex ratio of 9,654 birds taken prior to November 18 was 194 cocks to 100 hens, or slightly more than 1 hen to every two cocks. Table 2 shows that the percentage of hens in the bag rose from the first to the third week, and then fell sharply.

The trend of the first three weeks results from increasingly poorer hunting and possibly from increasing wildness of male birds. The rise in the sex ratio of the kill for the fourth week is probably due to the small sample, over half of which came from an area where the ratio was consistently high throughout the season.

The bulk of the kill occurred during the first half of the season when both cocks and hens were being taken, and

the data of that period are probably fairly representative for the season. Shooting only cocks during the latter half of the season raised the proportion of cocks in the kill but this was offset by the illegal and unrecorded kill of hens throughout the season. The kill for 1946, therefore appears to be composed of about one-third hens. This high kill of hens was perhaps justified in view of the strong sentiment in the in the fall of 1946 among farm groups over damage resulting from high pheasant populations in some areas. Until reproduction improves considerably, hens should be protected to give the declining population the best possible chance for recovery.

WEIGHTS

A total of 4,718 pheasants were weighed during the 1946 hunting season. Gram scales were not available and weights were taken on Hanson postal scales which weighed up to 5 pounds by one ounce graduations.

Weights were tabulated by dates, counties, and sex-age classes, and these data condensed to give Table 3. Adult cocks (1,307) averaged 47 ounces, (2 lbs. 15 oz.), 1,979 young cocks averaged 42 ounces (2 lbs. 10 oz.), 559 adult hens averaged 34 ounces (2 lbs. 2 oz.), and 873 young hens averaged 31 ounces (1 lb. 15 oz.).

The heaviest bird recorded, an adult cock checked at Mitchell in Davison County on December 1, weighed 4 lb. and 2 oz. The smallest adult male weighed 2 lb. and 6 oz. Juvenile males ranged from 1 lb., 15 oz. to 3 lb., 9 oz. Weight ranges for hens were from 1 lb., 13 oz., to 3 lb., 1 oz. for adults; and from 1 lb., 2 oz., to 2 lb., 15 oz. for young hens.

TABLE 3.—AVERAGE PHEASANT WEIGHTS BY 6 DAY PERIODS—1946

	October						November										December						Ave. Wt. oz.
	15–20		21–26		27–1		2–7		8–13		14–19		20–25		26–1		2–7		8–13				
	No.	Wt. oz.	No.	Wt. oz.	No.	Wt. oz.	No.	Wt. oz.	No.	Wt. oz.	No.	Wt. oz.	No.	Wt. oz.	No.	Wt. oz.	No.	Wt. oz.	No.	Wt. oz.	Total		
Old Cocks	343	46.0	199	48.0	271	47.0	169	46.5	81	47.3	149	47.0	27	45.7	67	47.2			11	49.1	1,307		46.9
Young Cocks	587	40.9	353	42.7	394	41.7	227	43.0	115	41.9	167	41.8	49	40.6	69	42.6			18	41.8	1,979		41.8
Old Hens	121	33.1	113	35.0	141	33.6	97	33.6	46	33.8	41	34.4									559		33.8
Young Hens	159	30.4	190	31.7	190	31.0	167	31.1	106	31.8	61	32.3									873		31.3

Weights of adult South Dakota pheasants in October, November and December are compared with similar data from other states in Table 4.

TABLE 4.—WEIGHTS OF ADULT PHEASANTS FROM SOUTH DAKOTA AND OTHER STATES

State	Date	Average Weight	
		Males	Females
Indiana (pen reared birds)*	November	3 lbs., 1 oz.	2 lbs., 3 oz.
Michigan**	Oct.–Dec.	2 lbs., 15 oz.	2 lbs., 1 oz.
Nebraska**	December	3 lbs., 5 oz.	2 lbs., 6 oz.
Ohio**	All months but mostly fall	2 lbs., 12 oz.	2 lbs., 3 oz.
Utah**	November	2 lbs., 8 oz.	—
South Dakota	Oct. 15–Dec. 13	2 lbs., 15 oz.	2 lbs., 2 oz.

* Kirkpatrick, 1944.
** McAtee, 1945.

Weights of birds from South Dakota, Michigan and Indiana are almost identical; while Nebraska birds are considerably heavier. Female pheasants from Ohio weighed about the same as those from South Dakota, but males were somewhat lighter. Males from Utah were considerably lighter than those from the other states.

Increases in weights during the season are shown for all age-sex classes in Figure 1 where average weights are plotted by 3 day periods. These data have been interpreted in the light of last year's weight data and the growth curves of pen-reared pheasants described by Kirkpatrick (1944).

From Figure 1 it will be seen that on October 15, adult cocks averaged 46.6 ounces, juvenile cocks 41.0 ounces, adult hens 33.0 ounces and juvenile hens 30.4 ounces. During the next 30 days, adult cocks made a 1.5 per cent gain and weighed 47.3 ounces, .7 ounces heavier. Juvenile males gained 1.5 oz., twice as much as the old cocks, and weighed 42.4 oz., a gain of 3.7 per cent. Adult hens gained much more than adult cocks and slightly more by per cent than juvenile males, increasing 1.3 ounces or 3.9 per cent, to weigh 34.3 oz. The most rapid weight increase occurred in young hens which gained 1.8 oz. in the 30 day period, a gain of 5.9 per cent. During the second 30 day period, only cocks were being shot, so no data were obtained on hens. Data for cocks were fewer and less reliable than in the first 30 days, but they indicated that adult cocks continued to gain weight while weights of juvenile cocks either leveled off or began to decline. Kirkpatrick found that the weights of juvenile males, hatched on May 19, reached their peak in mid-December and then declined very gradually until April when they dropped sharply. The leveling off of weights of juvenile males in mid-November as shown in Figure 1 occurred a month earlier, in spite of the fact that most of our birds probably hatched later than those in Kirkpatrick's study. Last year's data suggest that the peak then was not reached until late December or early January. For these reasons the curve is believed to be inaccurate for the second month of the season. This is substantiated by the difference in weight between adult and juvenile cocks on December 13,

amounting to 5.5 ounces, since juvenile cocks should normally attain weights almost equal to those of adult males by mid-winter of their first year. Further substantiation is found in the weights of birds checked at Mobridge and Mitchell where good samples were obtained

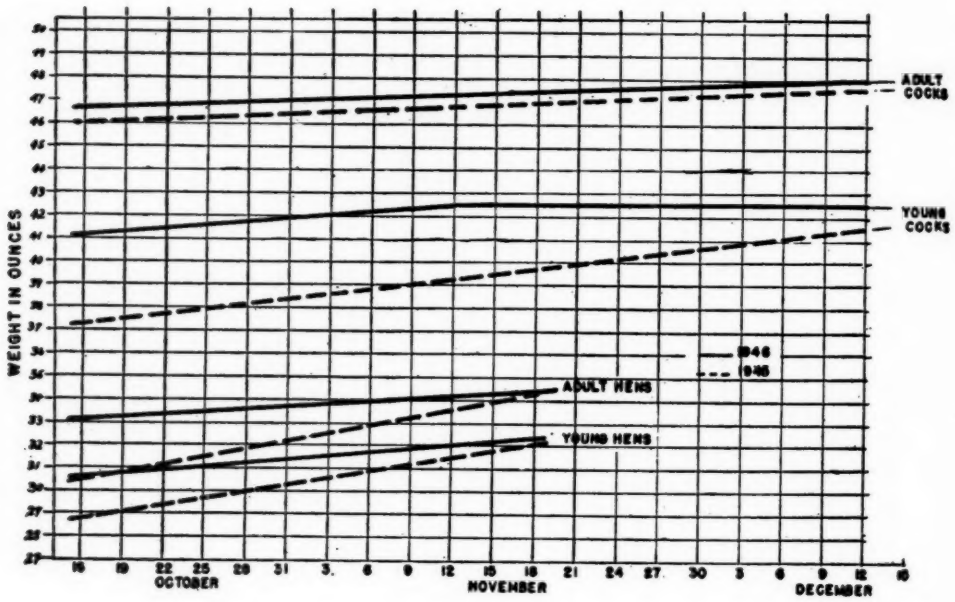

FIG. 1.—Weight changes of ring-necked pheasants by sex and age classes during the fall of 1945 and 1946.

throughout the season. In these cases weights of young cocks continued to increase during the period.

Adult hens put on weight rapidly during the period, probably regaining that lost during the nesting season. On November 15 their average weight was 34.3 ounces, compared with an average weight of 34.0 ounces for adult hens at the same time in 1945.

A point of interest is the weight gain from October 15 to November 15, 1946, which was only about half as rapid as that of 1945 for the same period. This probably was because the 1946 hatch was more successful with less renesting, allowing hens to regain weight earlier in the fall.

Young hens had a more rapid growth rate than any other group, increasing in weight by 5.9 per cent during the period. Why they should have gained more rapidly than young cocks was not determined.

The data for 1945 and 1946 show a less rapid growth rate for juveniles in 1946. This is due to an earlier hatch in 1946, with the result that juveniles had passed further through the period of most rapid growth. Juvenile cocks and hens were 3 and 1.4 ounces heavier respectively on November 15, 1946 than on the same date in 1945, reflecting an

earlier average hatching date on the whole for 1946. For the two years included in the study, more successful reproduction was correlated with earlier hatches, while late hatches resulted in poor reproduction.

Studies in Missouri (Denny, 1944) and elsewhere have shown that weights of game birds and mammals vary directly with soil fertility. The locations where the birds weighed last fall in South Dakota were killed were not accurately enough known to relate weights to soil types except in a general way. Weights of adult cocks were used because they should show the least variation from other factors such as date of hatching and weight changes due to varying lengths of nesting and brood rearing efforts. In order to afford a large sample, the weights of all adult cocks were used, after adjusting them to November 14 from the weight increase curve. These data show that birds from southeastern South Dakota and the eastern border counties were heavier than average for the state, while the lightest birds came from an area north and west of there. Birds from several north-central counties were medium weight or heavier. The soils of the area from which the heavier birds came are largely Barnes loam and Barnes silt loam, the latter type not occurring elsewhere in the state to any extent.

Weights of juvenile males were treated in a similar manner with the thought that they might reflect differences in hatching dates. However, when plotted on a map they fell in the same pattern as the weights of adult males, with the heaviest birds coming from eastern and southeastern counties. Seemingly, the weight differences resulted from the same factors responsible for weight differences among adult males, rather than from variations in hatching dates.

METHODS OF AGE DETERMINATION

In the course of this study, 1,156 birds aged by bursa of Fabricius examination were also aged by one or more other methods to determine their accuracy. The age by bursa was used as the standard by which other methods were checked. The presence of a shallow bursa in adult birds was again noted this year and on the basis of spur lengths, weights and other conditions, a bursa depth of 10 mm. was established as the maximum for old birds. Birds with greater bursa depths were considered to be young of the year.

The Kimball age gauge was checked against the bursa for 614 male pheasants. Bursa examination aged 221 of these as adults and 393 as young. On adults, the age gauge erred in 13 cases giving it an accuracy of 94.1 per cent. In the case of young birds 32 were incorrectly aged by the gauge, giving an accuracy of 91.9 per cent.

Considering the group as a whole, some compensation occurred and the total number of errors was 19 in 614 cases, resulting in a compensated accuracy for the gauge of 96.9 per cent.

The age gauge was more accurate during the first two weeks of the season (October 15–October 31) than in November and December. In October, 10 of 132 adults were classed as juveniles and 10 of 219 juveniles classed as adults, so the errors compensated completely and the gauge gave identical results with the bursa. In November and the first half of December as spurs

increased in length, the error for adults decreased, but that for young birds increased considerably, and the total compensated error was 7.5 per cent for 253 birds checked.

The age gauge erred more often on young birds than on adults, and largely on birds whose spur lengths were 19 and 20 mm., just above and below 19.5 mm., the diameter of the gauge.

Some inaccuracies occur in age determination by the bursa method, also. However, the bursa method was believed to be the most accurate available and for that reason was used as the standard for checking the age gauge. It is possible that some errors charged to the gauge were actually errors in the bursa method, and the accuracy of the gauge may be higher than shown. Both methods are reliable enough for practical purposes.

The strength of the lower mandible has been used as an indicator of age. The lower mandible of adults is supposed to be strong enough to support the weight of the bird when held by the tip of the mandible, while in young of the year it should break. This method, checked against the bursa for 542 cocks, was found to err on 24 of 180 adults and on 54 of 362 young birds. It had an accuracy of 92.2 per cent for adult birds and an accuracy of 81.5 per cent for young birds. Of the total number of birds (542), 210 were classed as adults by the mandible test compared with 180 so classed by bursa examination. Thus there were 30 cases in error, resulting in a compensated accuracy of 94.5 per cent. The ages of 486 hens were determined by both bursa examination and the lower mandible test, and the latter method found to be accurate in 319 or 65.6 per cent of the cases, an error of 34.4 per cent. This is the uncompensated error, but since most of the errors occurred in classing adults as juveniles, the compensated error would not be much less.

SPUR LENGTHS

Spur length measurements were taken on 2,198 cock pheasants during the 1946 hunting season—1,357 juveniles and 841 adults (according to this criterion). These data were tabulated by 2 week periods for each of 6 areas of the pheasant range. The counties included in each area follow:

NORTHWEST—Walworth, Campbell, Dewey, Corson, Edmunds, McPherson.

NORTHEAST—Brown, Roberts, Day.

WEST CENTRAL—Hughes, Sully.

CENTRAL—Beadle, Spink, Faulk, Hand.

EAST CENTRAL—Brookings, Hamlin, Codington, Deuel, Kingsbury, Miner, Lake.

SOUTH—Jerauld, Sanborn, Brule, Aurora, Davison, Hanson, McCook, Hutchinson, Yankton, Bon Homme, Douglas, Gregory, Tripp, Bennett.

The spur length, as used here, actually includes the diameter of the tarsus, being the distance from the tip of the spur to the opposite side of the tarsus. Measurements were taken with calipers graduated in millimeters.

Growth in length of the spurs was determined from the average spur lengths by 2-week periods. These data are shown in Table 5 and in Figure 2, where they are also compared with similar data from the 1945 season. During the two months from Oct. 15

TABLE 5.—SPUR LENGTHS OF COCKS BY TWO-WEEK PERIODS—1946

Date	Young		Adult	
	No. of Birds	Ave. Spur Length (mm.)	No. of Birds	Ave. Spur Length (mm.)
Oct. 15–31	942	16.1	531	22.3
Nov. 1–15	277	16.5	217	22.4
Nov. 16–30	107	16.5	70	22.3
Dec. 1–13	31	17.2	23	23.1
Oct. 15–Dec. 13	1,357	16.25	841	22.37

to Dec. 13, the increase in the length of the spurs of adult males was about .5 mm. in both years. The difference between the average spur length of adult cocks in 1945 and 1946 was only .5 mm. and is not considered significant.

Greater increases are apparent in the spur lengths of young cocks, as would be expected. The growth in spur length was 1.7 mm. in 1945 and 1.3 mm. in 1946 for the two month period. The data show smaller average spur lengths for 1945 than 1946. These facts correspond with weight differences for the

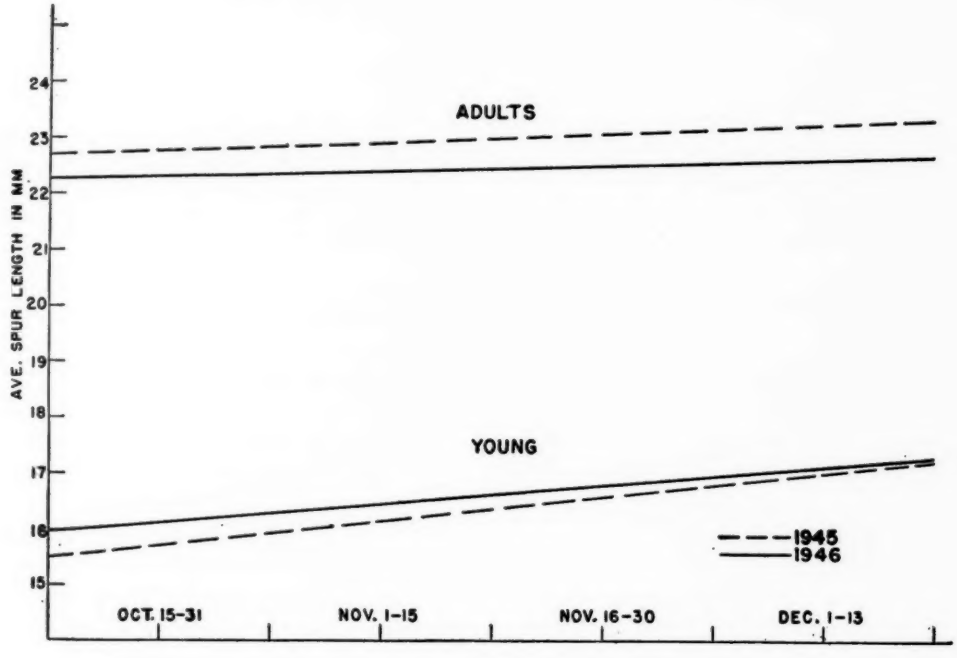

FIG. 2.—Growth in spur lengths of adult and young pheasants for the period Oct. 15 to Dec. 13, 1945 and 1946.

two years, the smaller size and the greater growth rate for 1945 birds pointing to a later hatch in that year.

The average spur lengths of cocks during the last half of October are tabulated by areas and age classes in Table 6. In the case of adults, the greatest spur lengths were recorded in the northeast, east-central, south, and

graphs in Figure 3, showing the frequency distribution of young cocks by spur lengths for different areas reveal a consistent difference between the areas of best and poorest reproduction. The northwest, northeast, and south, the areas of best reproduction, have more uniform curves without the marked double peaks which appear in

TABLE 6.—AVERAGE SPUR LENGTHS OF COCKS BY AREAS AND AGE CLASSES, OCT. 15–31, 1946

Area	Young		Adults	
	No. Birds	Ave. Spur Length (mm.)	No. Birds	Ave. Spur Length (mm.)
Northwest	264	16.1	198	22.0
Northeast	25	16.7	2	22.5
West-Central	16	16.0	14	22.4
Central	24	16.6	21	20.9
East-Central	213	15.6	117	22.5
South	400	16.4	179	22.6

west-central parts of the range. Except for the west-central area, which is represented by a small sample, these data substantiate the conclusions drawn from the weight data, that pheasants are larger in the southern and far eastern parts of the pheasant range.

The spur lengths of young birds from the east-central area were considerably lower than those from the rest of the pheasant range, suggesting that early nesting attempts were not very successful and that a considerable portion of the young of the year were made up of birds from renesting efforts. This area is part of the central zone of poor reproduction.

The frequency distribution of young cocks by spur length classes was compiled and plotted for each area for the period Oct. 15–31 (Figure 3). The

the curves for the areas of poorest reproduction. The normal curve for frequency distribution of spur lengths of even aged birds probably has little dispersion and is quite peaked. The curve of a sample of birds from an area having good reproduction should approach the normal curve, but have greater dispersion and be skewed somewhat to the right, due to the natural spread of hatching dates and a small amount of late nesting or renesting which always occurs. With adequate sampling of spur lengths of young cocks, it may be possible to measure the degree of reproductive success of any area by comparing its frequency distribution of spur lengths with a standard representing good reproduction.

In Figure 4, the frequency distribu-

tion of spur lengths of young cocks is shown for 1945 and 1946. Better reproduction in 1946 is reflected in the curve for that year, which approximates more nearly the conception of the curve for good reproduction. A greater amount of renesting in 1945 appears in the curve as a larger percentage of birds falling in spur length classes lower than that of the peak, so that the curve is skewed to the right to a greater degree.

Analysis of spur length data may be useful in evaluating reproductive success in pheasants, especially in areas where it is difficult to examine large numbers of birds in the field or in locker plants. Pheasant feet saved by cooperating sportsmen will reveal the age ratio in the bag but they will apparently also provide more detailed information on the success of first nests and the extent of re-nesting.

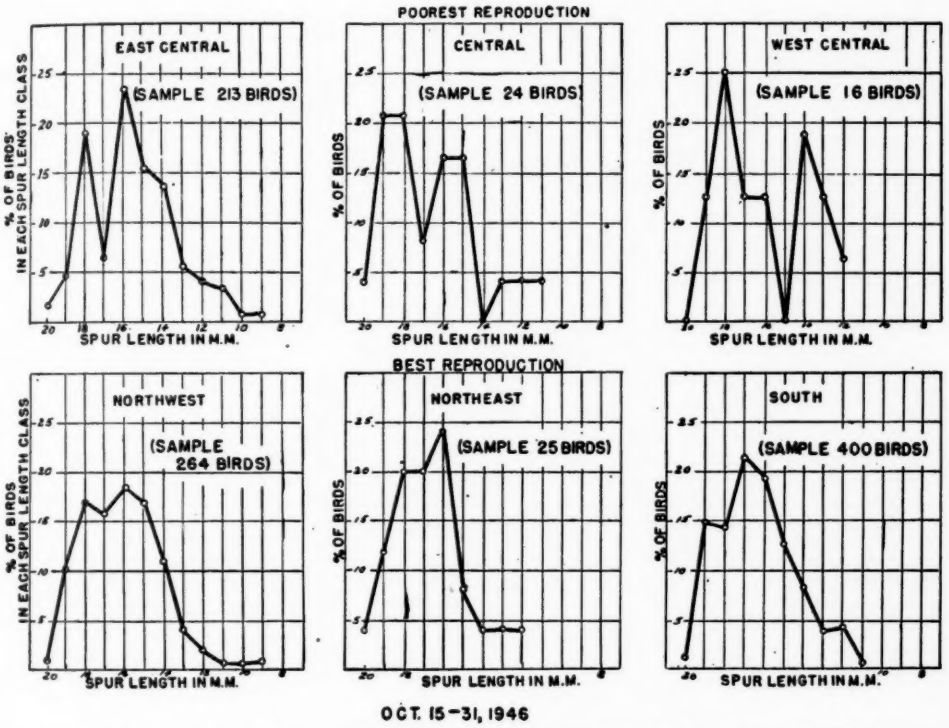

FIG. 3.—Comparison of frequency distribution of young cocks by spur lengths. The upper 3 graphs are for areas of poorest reproduction and the lower 3 are for the areas of best reproduction.

SUMMARY

1. The age ratio of 6,896 pheasants checked from October 15 to December 13, 1946 was 1.53 young per adult, only about half of normal, but better than the 1945 age ratio of 1.00.

2. Reproductive success was best in the southeastern and northeastern parts of the pheasant range, poorest

in the central and about average in the northwestern part of the range.

3. The proportion of young birds killed was highest in the early part of the hunting season.

4. The sex ratio of the kill, from a sample of 9,654 birds, was 194, or about 2 cocks to every hen. The kill in 1946 was therefore composed of about ⅓ hens.

5. A total of 4,718 pheasants was weighed during the season. Average weights were: adult cocks, 46.9 oz., young cocks, 41.8 oz., adult hens, 33.8 oz., and young hens 31.3 oz.

6. The rate of weight increase during the period Oct. 15–Nov. 15, 1946 was

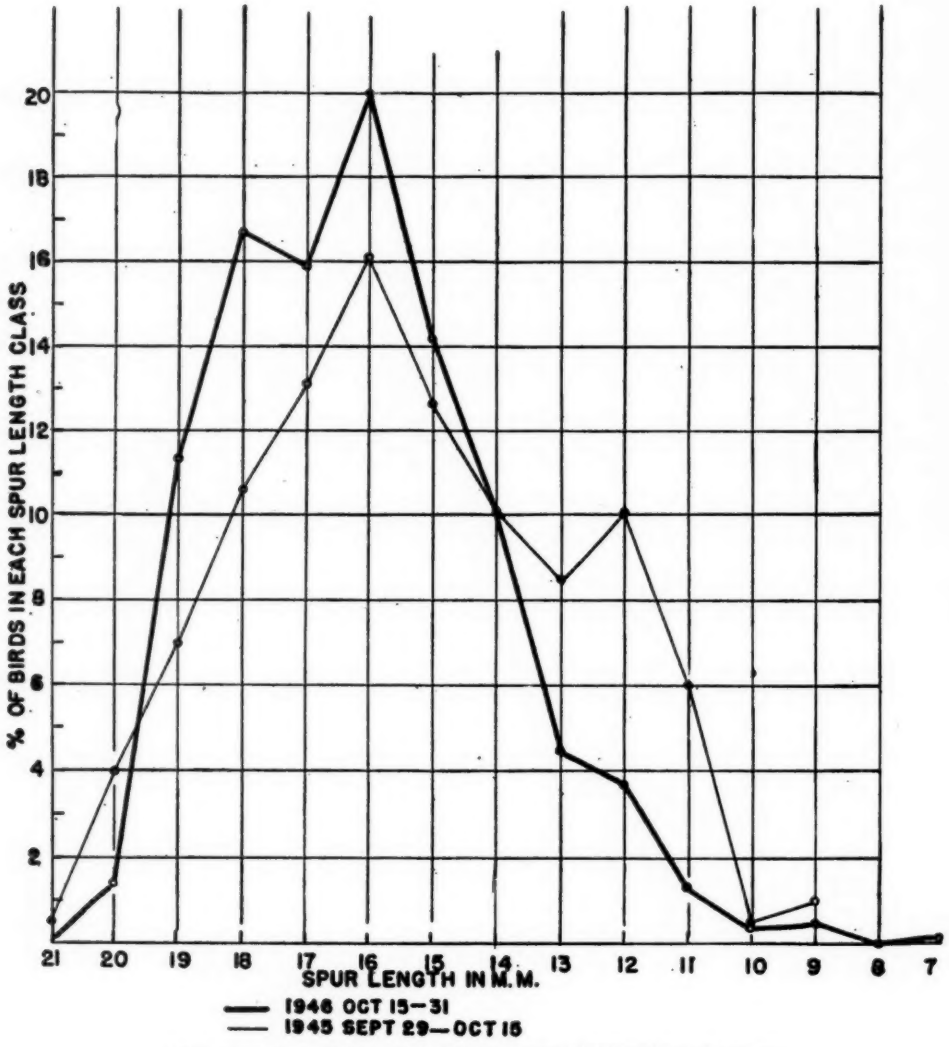

FIG. 4.—Comparison of the frequency distribution of young cocks by spur lengths, 1945 and 1946.

greatest for young hens, followed by adult hens, young cocks and adult cocks in the order given. The increase in weight ranged from 1.8 oz. for young hens to .7 oz. for adult cocks.

7. Young birds averaged heavier in 1946 and had a lower growth rate, due to an earlier and more successful hatch than in 1945.

8. Southeastern and eastern South Dakota produced heavier birds than the rest of the state. Greater average weights appear to be correlated with the occurrence of the Barnes silt loam soil type in the state.

9. The Kimball age gauge, checked against bursa examination on 614 cocks, had a compensated accuracy of 96.9 per cent. The lower mandible test, checked against bursa examination on 542 cocks, had a compensated accuracy of 94.5 per cent. The same method, checked against the bursa on 486 hens, had an uncompensated accuracy of 65.6 per cent.

10. Growth in spur length between Oct. 15 and Dec. 13 was 0.5 mm. for adult cocks and 1.3 mm. for young cocks. Spur lengths of young cocks were greater and had a lower growth rate in 1946 than in 1945, due to an earlier hatch.

11. The greatest average spur lengths were from adult cocks checked in the same areas that produced the heaviest birds. Low spur lengths of young cocks from east central South Dakota are believed to be related to the poor reproduction in that area.

12. Frequency distribution of young cocks by spur lengths for 6 portions of the pheasant range revealed the same pattern of reproductive success as age ratios and other data.

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CALCIUM AND PHOSPHORUS REQUIREMENTS OF BOBWHITE QUAIL CHICKS

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The most prominent function of calcium and phosphorus is, of course, the formation of the skeleton, approximately 99 per cent of the calcium and 80 per cent of the phosphorus of the body being present in the bones. Nevertheless, in addition to this very weighty role, these minerals have a significant part in maintaining the necessary osmotic pressure and surface tension of the body-fluids, regulating the hydrogen ion concentration of blood and tissues, maintaining acid-base equilibrium, acting as integral portions of living protoplasm, and influencing the response of muscles and nerves to stimuli. Serum calcium also, like vitamin K, is essential for the clotting of blood.

These two elements, like other minerals taken into a vertebrate animal's body, are constantly being excreted in the urine and feces. An excess of either one, if within a reasonable range, is rapidly eliminated. If a deficiency exists, the body conserves its supply and lowers its normal excretion.

Branion (1938) after an extensive review of the literature, was led to believe that the ratio between the quantity of calcium and that of phosphorus in any diet must be of some importance, inasmuch as an excess of one results in depletion of the other for excretory purposes. An optimum Ca:P ratio in the diet apparently lessens the requirement for vitamin D, but with a vitamin D deficiency, no Ca:P ratio will produce good bone. Absolute quantities of calcium and phosphorus often are more important than the ratio, the latter occurring as a natural sequence. It is quite possible to devise a diet with a good Ca: P ratio, but furnishing inadequate or excessive quantities of both minerals. From a resume of evidence obtained from 35 sources on the calcium and phosphorus requirements for growth and bone formation, Branion concluded that the minimum calcium requirement for domestic chicks would seem to be about 0.7 per cent, and that of phosphorus as 0.4 per cent. However, to provide a margin of safety, without danger of overdosage, he recommended that practical chick diets probably should furnish about 1.0 per cent calcium and 0.5 per cent phosphorus (See also Ewing, 1941).

From analyses of the entire carcases of domestic chicks, Titus (1939, 1941) found that for each part by weight of phosphorus retained from the feed, about 1.5 parts of calcium are also retained. Likewise, according to analyses of both the feed consumed and of the carcass, the minimum calcium requirement of the chick, when expressed as per cent of the diet, decreases with age. The minimum calcium and phosphorus requirements of very young chicks are met by a diet containing about 0.75 and 0.55 per cent of these elements respectively. Observations on the excretion of excess calcium and

phosphorus suggest that from a physiological standpoint these two elements are most easily eliminated in a ratio of about 1.3:1. The ratio of calcium to phosphorus may vary from 1.3:1 to 2:1, with the optimum ratio probably between 1.5:1 and 2:1. Titus concluded that it would be a good practice for both chicks and poults to have the diet contain not less than 0.7 per cent of phosphorus, and adjust the calcium content so that there are about 1.6 times as much of the latter as the former.

Callenbach and Murphy in 1935 (unpublished data) pioneered in research on the mineral requirements of gamebirds, by conducting experiments at Pennsylvania State College on ring-necked pheasants, using calcium levels from 0.5 to 3.0 per cent, and phosphorus levels from 0.5 to 1.0 per cent. Their results indicate that for battery-reared pheasants a diet containing 1.5 per cent of calcium and 0.75 per cent of phosphorus gives satisfactory growth and sound bone development.

Skoglund's work (1940) on the same bird involved calcium levels from 0.87 to 2.64 per cent, phosphorus levels from 0.78 to 1.08 per cent, and Ca:P ratios from 1.11:1 to 2.68:1. At the end of eight weeks, the pheasants on 0.87 per cent calcium and 0.78 per cent phosphorus outranked all others in weight. Results were statistically signficant. Skoglund nevertheless concluded "that any practical ration containing under 2.84 per cent calcium and 1.08 per cent phosphorus would be within the limits which pheasants can tolerate, provided the manganese content of the ration is about 35 parts per million."

A knowledge of fundamental principles is necessary in the development of an enlightened program for the improvement of gamebird habitat. In order for valid recommendations to be made regarding food-plantings and feeding stations, there should be information on the dietary requirements and preferences of game, as well as the nutritive value of foods. Much of such information can be obtained only under conditions of controlled research where as many variable factors as possible can be eliminated.

The questions arise: Would a lack of lime or phosphates under natural conditions affect adversely a quail population? If so, how seriously, and in what way? A search of the literature has disclosed no experiments reported on the mineral requirements of the bobwhite quail (*Colinus virginianus*). Therefore, during 1946 four successive studies, involving 873 quail chicks, were conducted at the Patuxent Research Refuge, Laurel, Maryland, to determine the minimum and optimum calcium and phosphorus requirements of growing quail. Later reports will be published on requirements of mature quail, for both breeding and maintenance.

PROCEDURE

Within twenty-four hours after hatching, quail chicks were so distributed on each experiment that, so far as was possible, an equal number of chicks representing each Ca: P ratio fed in the parents' diet (1:1, 1⅔:1, 2⅓:1, 3:1, 3⅔:1, and 4⅓:1, at a phosphorus level of 0.75 per cent) was started on each growth diet.

In order to form the various diets, a basal feed mixture consisting of ground yellow corn, 38 parts by weight, ground

wheat, 10, soybean oil meal, 41, liver meal, 10, and salt mixture (100 parts iodized salt plus 1.7 parts of anhydrous manganous sulfate), 1, was combined with 0.5 part of vitamins A and D feeding oil fortified (3,000 I.U. of vitamin A and 425 I.U. of vitamin D per gram), tricalcium phosphate, and calcium carbonate or high-calcium limestone. Four phosphorus levels were studied, namely, 0.52, 0.75, 1.00, and 1.25 per cent; and at each level (except that of 1.25 per cent), six Ca: P ratios were compared, namely, 1:1, 1½:1, 1⅔:1, 2:1, 2½:1, and 2⅔:1. On the 1.25 per cent level of phosphorus, the 1:1 ratio was omitted. Each diet was fed to duplicate pens. No grit or dusting sand was given to the quail.

Birds were weighed within 24 hours after hatching and every two weeks thereafter for ten weeks. Records were kept on quantity of feed consumed and wasted. At the end of ten weeks, eight birds from each diet were sacrificed, proper consideration being given to their parental background. Livers were assayed for vitamin A storage by spectrophotometric method, and both tibiae of each bird were analyzed for total ash content.

All data but that on feed consumption, were analyzed statistically by variance analysis (Fisher's "t" and "z" tests, 1932; Titus and Hammond, 1935).

RESULTS

Results at the end of ten weeks are summarized in Tables 1 and 2.

Survival. There was a high percentage of survival on most of the diets. Only three groups of quail showed losses of more than 30 per cent, namely, those on phosphorus levels of 0.52, 1.00, and 1.25 per cent, with Ca: P ratios of 1:1, 2:1, and 2:1 respectively. None of the differences, however, were statistically significant.

Live weights. Significantly higher weights were obtained on the levels of phosphorus of 0.75, 1.00, and 1.25 per cent than on the lowest levels of 0.52 per cent. Most of the birds on the 0.52 per cent of phosphorus averaged less in weight than the majority of the quail raised at the Refuge during the past seven years.

Although the birds on the Ca: P ratio of 1:1 averaged the lowest weight, 139 grams, nine grams less than that of the quail on the next ratio, the differences were not statistically significant.

Feed consumption. Consumption of feed increased in direct proportion with the increase in level of phosphorus. No correlation existed between Ca: P ratio and feed consumption.

TABLE 1.—SUMMARY OF RESULTS FROM QUAIL CHICKS FED VARIOUS LEVELS OF PHOSPHORUS AND CALCIUM

Results Through Tenth Week of Age	Levels of phosphorus (%)				Calcium-Phosphorus ratios					
	0.52	*0.75*	*1.00*	*1.25*	1:1	1½:1	1⅔:1	2:1	2½:1	2⅔:1
Survival (Per cent)	81	85	75	74	76	83	78	74	84	78
Average live-weight (grams)	136	149	147	149	139	148	143	146	145	143
Food Consumption (grams per bird per day)	7.4	8.6	8.5	9.9	7.8	8.8	8.3	8.5	8.7	8.5
Efficiency of feed utilization (grams feed per gram gain in weight)	4.1	4.3	4.3	4.9	4.3	4.2	4.4	4.3	4.3	4.4
Ash of tibiae (Per cent)	*60*	*63*	*62*	*61*	*59*	*62*	*62*	*62*	*62*	*63*
Storage of vit. A (I.U. per gram liver)	210	210	210	190	230	220	220	200	200	170

Efficiency of feed utilization. The greatest efficiency was on the 0.52 level of phosphorus. The highest level of phosphorus, 1.25 per cent, was utilized less efficiently than any of the others. Differences are highly significant. Differences in efficiency of feed utilization as a result of the Ca: P ratio, are not significant.

Ash of tibiae. The bone-ash of birds on 0.75 per cent of phosphorus was significantly greater than that of quail on either 0.52 or 1.25 per cent. Ash of quail on 1.00 per cent phosphorus, likewise, was greater than that of the birds on the highest and lowest levels, but only in the case of the latter were differences statistically significant.

Birds on all Ca: P ratios above 1:1 showed significantly greater bone-ash than that on 1:1.

Vitamin A storage. The level of phosphorus had no effect on the storage of vitamin A in the liver.

The storage of vitamin A tended to decrease as the Ca: P ratio grew wider. Storage on the ratios of 1:1, 1⅓:1, 1⅔:1, 2:1, and 2⅓:1 was significantly greater than that on 2⅔:1. However, the odds on the difference between either 2:1 or 2⅓:1 and 2⅔:1 were only 19:1, whereas those on the difference between either 1⅓:1, 1⅔:1, or 1:1 and 2⅔:1 were according to the order of 99:1.

SUMMARY AND CONCLUSION

Four experiments involving 873 bob-

TABLE 2.—COMPARISONS AND SIGNIFICANCE OF RESULTS SUMMARIZED IN TABLE 1, BASED ON VARIANCE ANALYSIS

	Level of phosphorus		Calcium-Phosphorus ratio	
	"z" test	"t" test	"z" test	"t" test
Survival	NS		NS	
Average live weight	HS	0.75>0.52 (HS) 1.00>0.52 (HS) 1.25>0.52 (HS)	NS	
Efficiency of utilization	HS	0.52>0.75 (HS) 0.52>1.00 (HS) 0.52>1.25 (HS) 0.75>1.25 (HS) 1.00>1.25 (HS)	NS	
Ash of tibiae	HS	0.75>0.52 (HS) 1.00>0.52 (S) 0.75>1.25 (S)	HS	1⅓:1>1:1 (HS) 1⅔:1>1:1 (HS) 2 :1>1:1 (HS) 2⅓:1>1:1 (HS) 2⅔:1>1:1 (HS)
Storage of Vit. A	NS		HS	1 :1>2⅔:1 (HS) 1⅓:1>2⅔:1 (HS) 1⅔:1>2⅔:1 (HS) 2 :1>2⅔:1 (S) 2⅓:1>2⅔:1 (S−)

S = Significant, odds of 19 to 1.
HS = Highly significant, odds of 99 to 1.
NS = Not significant.

white quail (*Colinus virginianus*) chicks were conducted at the Patuxent Research Refuge, Laurel, Maryland. A comparison was made of calcium: phosphorus ratios of 1:1, 1⅓:1, 1⅔:1, 2:1, 2⅓:1, and 2⅔:1 in diets with phosphorus levels of 0.52, 0.75, 1.00, and 1.25 per cent. The results indicate that the optimum level of phosphorus for growth is in the neighborhood of 0.75 per cent, and that of calcium is about 1.00 per cent, making a ratio of 1⅓:1.

Although the greatest efficiency of feed utilization occurred on the phosphorus level of 0.52 per cent, the liveweight and bone-ash of the birds at the end of ten weeks were significantly lower than they were on the levels of 0.75 and 1.00 per cent phosphorus. Bone-ash of birds on a Ca: P ratio of 1:1 was significantly lower than that on any of the other five ratios, regardless of phosphorus level.

There was a significant reverse correlation between the Ca: P ratio of the diet and the storage of vitamin A in the liver. Storage was especially low on the ratio of 2⅔:1.

The low and high levels of calcium and phosphorus considered in these studies are abnormal, the low level especially being hard to obtain with common feedstuffs, if the protein requirements of the birds are met. Nevertheless, even on such levels, results were not disastrous. The growth of quail in the wild happens during a season when the birds have access to the minerals of the soil and in the abundant animal matter (mostly insects), as well as to minerals in plant material. Therefore, seemingly, calcium and phosphorus need not be critical nutrients for growing quail in the wild.

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WINTERING BOBWHITE IN BOONE COUNTY, MISSOURI[1]

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Between January 1, 1946, and April 1, 1947, seasonal studies of quail populations (*Colinus virginianus*) were conducted on two study areas in Boone County, Missouri: New Salem and West Ashland. The areas are considered average farmland for central Missouri and their nearest corners are one mile apart.

The object was twofold: to learn, by analysis of winter range, some of the principal factors determining winter carrying capacity; and to appraise the early effects of agricultural land improvements upon the quail population of the West Ashland area.

Areas

NEW SALEM: The area contains 2,260 acres, and its nearest boundary is one mile north of Ashland. The topography is undulating and erosion has been moderate. It is considered Class III land. On the whole relatively high standards of agriculture have been maintained, though land improvements have been made solely through the farmers' initiative and have not been extensive in any year. There is a fair interspersion of crops and cover, and winter food and cover conditions are better than on adjoining lands. Evidence of predation has been negligible. There are a few Cooper's hawks (*Accipiter cooperi*), great horned owls (*Bubo virginianus*), red foxes (*Vulpes fulva*), minks (*Mustela vison*), and dogs and cats, but also there is a high buffer population of rodents and rabbits. Hunting pressure is average for this region. Unfortunately, it was impossible with available manpower to measure the hunter's kill.

WEST ASHLAND: The area contains 2,070 acres, and its nearest boundary is one mile west of Ashland. The topography is undulating to rolling. It is considered Class V-VII land. Excessive cultivation and grazing have reduced soil fertility, and erosion has been moderate to severe. At the beginning of the study, 14 per cent of the farmland had been abandoned and old fallow fields were in the perennial weed-intolerant tree stage of succession. This provided good cover but poor food. Some of this idle land has since been returned to cultivation, and where border cover is left food conditions are now more favorable for birds than before. Contrasted to the New Salem area, conditions of winter food and cover at the beginning of the study were poorer here than on adjoining lands. Cooper's hawks were seen more frequently than on the New Salem area and predation may be more extensive, even though there is a high buffer population of

[1] Contribution from the Missouri Cooperative Wildlife Research Unit, U. S. Fish and Wildlife Service, Wildlife Management Institute, Missouri Conservation Commission, Edward K. Love Foundation, and University of Missouri cooperating. Robert L. Dunkeson, undergraduate at the University of Missouri, assisted the investigator during the summer.

rodents and rabbits. Here, too, it was impossible to measure the hunter's kill, but it is believed to have been greater than at New Salem.

In 1945, a relatively fast-moving program of land improvement was inaugurated through the cooperation of the farmers, the Missouri Conservation Commission, the Western Cartridge Division of Olin Industries, Inc., the Soil Conservation Service, and the Agricultural Extension Service. The landowners receive direct benefits through the Production and Marketing Administration (formerly the Agricultural Adjustment Administration) and additional financial aid from the Western Cartridge Company, under the direction of a full-time supervisor, Mr. George Quinn of the Missouri Conservation Commission. Most of the improvements have not had time to change greatly the nature of the environment of quail, since cover plantings and seedings are in early stages of development.

CENSUS METHODS

In order to ascertain the seasonal population and distribution of quail, each area was censused five times a year. Fall and winter censuses were conducted before and after the hunting season, which in Missouri lasts from November 10 through January 1. Spring censusing was conducted in March. Two summer censuses were made between June and September. A bird dog was used in the spring, fall, and winter, and tracking was done when snow made it possible. To avoid duplicate counts, each unit of occupied range was covered rapidly in one day. Covey movements between the units of occupied range were never observed. The "flush-count" method was used, except when the birds could be counted on the ground or by tracking. No "singles" were counted after flushing.

The effort to find all nests proved futile because of the density of the vegetation and the lack of time and assistance available. Instead, two methods of finding broods were employed: (1) Where the vegetation was open enough, a 100-foot clothesline weighted with tin cans, was dragged by two men. (2) In brush, beating with sticks proved most practicable; almost all of the broods were found along fencerows. The age of the birds in each was estimated from their size and ability to fly (Stoddard 1931: 72–81), and the approximate date of hatching was computed. When there was uncertainty as to the number of broods, either the farmers were consulted, another census was made, or both. It is believed that every adult bird was found except a very few incubating hens assumed to be present with nonwhistling cocks. The number of adult birds present during the summer is shown as the nesting population in Table 1.

CENSUS RESULTS

Table 1 shows the population of quail on each area during each census. Table 2 shows the summer productivity.

The population at New Salem in the first winter was twice that at West Ashland. New Salem showed a decrease of 33 per cent in population from winter to the nesting season; at the same time, West Ashland showed an increase of 13 per cent. This suggests a net ingress into the West Ashland

TABLE 1.—SEASONAL POPULATION OF BIRDS

Census	New Salem (2,260 acres)				West Ashland (2,070 acres)			
	No. Coveys or Broods	Av. No. Birds per Covey or Brood	Total No. Birds	Birds per 100 Acres	No. Coveys or Broods	Av. No. Birds per Covey or Brood	Total No. Birds	Birds per 100 Acres
Winter 1945–'46	11	13.5	149	6.6	8	8.9	71	3.4
Spring	10	12.9	129	5.7	7	8.6	60	2.9
Nesting	—	—	100	4.4	—	—	80	3.9
Summer	36	13.1	470*	20.8	28	12.7	356*	17.2
Fall	27	12.0	324	14.3	19	13.5	256	12.4
Winter 1946–'47	16	10.6	169	7.5	16	9.1	146	7.1
Spring	14	8.2	115	5.0	12	10.0	119	5.7

* In lieu of summer mortality—since summer mortality was unknown, this figure represents total summer production rather than actual population.

area and a net egress from the New Salem area between April and June. The nesting-population density of birds on the two areas was then nearly the same. Thus, in the first winter New Salem had better range than West Ashland; yet egress before the nesting season showed the relative inferiority of New Salem and superiority of West Ashland as nesting range, as compared with their respective adjoining lands.

The average May–June hatch brought off 71 per cent of the total young, with June (43 per cent) the peak month. The relatively large May hatch (28 per cent), unusually large for Missouri, was made possible by the unseasonably warm early spring. In March, covey associations were loose and the birds were rapidly leaving their winter ranges. Some clutches must have been completed by the second week in April, since some were hatched about May 1. These dates conform to those of Lehmann (1946) in Texas and Stoddard (1931: 20–21) in Florida and

TABLE 2.—SUMMER PRODUCTION OF BIRDS

Period of Hatch		New Salem				West Ashland			
		No. Broods	Av. Size of Brood	No. Birds	Per cent of Production	No. Broods	Av. Size of Brood	No. Birds	Per cent of Production
May:	1–15	4	15.3	61	*13*	2	15.5	31	*9*
	16–31	5	16.2	81	*17*	5	11.8	59	*17*
	(total)	9	15.8	142	*30*	7	12.9	90	*25*
June:	1–15	6	12.7	76	*16*	6	12.0	72	*20*
	16–30	8	14.3	114	*24*	7	13.1	92	*26*
	(total)	14	13.6	190	*40*	13	12.6	164	*46*
July:	1–15	3	10.7	32	*7*	1	15.0	15	*4*
	16–31	4	10.5	42	*9*	3	14.0	42	*12*
	(total)	7	10.6	74	*16*	4	14.3	57	*16*
Aug.:	1–15	1	11.0	11	*2*	3	12.0	36	*10*
	16–31	2	10.0	20	*4*	0	0.0	0	*0*
	(total)	3	10.3	31	*7*	3	12.0	36	*10*
Sept.:	1–15	2	9.0	18	*4*	1	9.0	9	*3*
	16–31	1	10.0	10	*2*	0	0.0	0	*0*
	(total)	3	9.3	28	*7*	1	9.0	9	*3*
Season (total)		36	13.1	470	*100*	28	12.7	356	*100*

Georgia, but are earlier than Errington's (1933a) in Iowa.

As many observers have found, the later broods decreased progressively in size. Disregarding adult mortality and the few old birds not counted with the broods, there was an increase during the summer of 345 per cent at West Ashland and of 370 per cent at New Salem. The smaller sizes of the early broods on the former area and the higher per cent production between July 16 and August 15 suggest somewhat more severe early losses of nests and young than those at New Salem.

From summer to fall, there was a loss of 28 per cent of the summer population at West Ashland and 31 per cent at New Salem. From fall to winter, the loss was 43 per cent and 47 per cent of the fall population respectively, due principally to hunting.

Most noteworthy is the percentage increase from winter to winter on the two areas. Although the two populations remained essentially the same and fluctuated together from spring to winter, there appeared then an increase of 106 per cent from the winter before at West Ashland and of only 13 per cent at New Salem. Thus, the population density at West Ashland, while only half that at New Salem in the winter of 1945–1946, almost equalled it the next winter. This suggests a sharp increase in winter carrying capacity at West Ashland.

While the population at New Salem was more than twice that at West Ashland in the spring of 1946, it was surpassed by that of West Ashland in the spring of 1947. A larger percentage of the birds wintered successfully at West Ashland than at New Salem. This is shown by the percentage decrease in the population on each area from November to April: 54 per cent at West Ashland, 65 per cent at New Salem. Errington (1941, 1945) has noted that normal winter loss is low as long as the population remains below its "threshold of security." If there had been no noticeable increase in carrying capacity at West Ashland, one would expect the normal winter loss to have been proportional to that at New Salem. The winter carrying capacity and agricultural practices remain fairly constant from year to year at New Salem.

Figure 1 shows the population trends, without regard to natural summer mortality. What is shown as egress and ingress is actually egress and ingress respectively plus and minus natural mortality. Also, the population peak shown represents the summer production peak rather than the true population peak. The true population peak doubtless occurred earlier in the summer and was less high, due to summer loss. Assuming that the rate of loss was accelerated by the hunting season, the probable summer trend may be diagrammed superficially.

WINTER RANGE

The birds were widely distributed during the nesting season, but during the late fall and winter they were clearly limited in range to the same parts in both years. This suggested an inquiry into factors accounting for such location preferences (*cf.* Table 3). Conclusions as to the factors affecting location preference are presented below under "Discussion."

Occupied winter range was largely restricted to three tracts comprising

TABLE 3.—RELATION OF WINTERING QUAIL TO CORN, LESPEDEZA, AND FENCEROW COVER

	West Ashland (2,070 ac.)					New Salem (2,260 ac.)						Both areas	
Range Number:	1	2	3	1–3	Other*	1	2	3	4	1–4	Other*	All	Other*
Total area (acres)	384	120	120	624	1,446	502	281	210	150	1,143	1,117	1,767	2,563
Miles fencerow	6.8	2.3	2.0	11.0	32.0	10.0	4.5	3.8	2.7	21.0	56.0	32.0	88.0
Miles cover**	5.0	1.3	1.5	7.8	6.3	4.0	1.7	1.5	1.5	8.7	4.2	16.5	10.5
% cover**	*74*	*56*	*75*	*70*	*20*	*40*	*39*	*40*	*56*	*42*	*8*	*51*	*12*
1945:													
Acres corn	88	14	0	102	78	100	58	32	30	220	147	322	225
% corn	*23*	*12*	*0*	*16*	*6*	*20*	*21*	*15*	*20*	*19*	*13*	*18*	*9*
Acres lespedeza	140	56	100	296	469	164	62	128	65	419	330	715	799
% lespedeza	*36*	*47*	*83*	*47*	*32*	*33*	*22*	*61*	*53*	*37*	*30*	*41*	*31*
Acres corn+lespedeza	228	70	100	398	547	264	120	160	95	639	477	1037	1024
% corn+lespedeza	*59*	*58*	*83*	*64*	*37*	*53*	*43*	*76*	*63*	*56*	*43*	*59*	*40*
No. wintering quail	36	8	15	59	12	66	15	14	34	129	20	188	32
% wintering quail	*50*	*11*	*21*	*82*	*18*	*44*	*10*	*10*	*23*	*87*	*13*	*85*	*15*
Quail per 100 acres	9.3	6.7	12.5	9.4	0.8	13.2	5.3	6.7	22.7	11.3	1.8	10.3	1.3
1946:													
Acres corn	144	5	15	164	94	81	77	74	70	302	241	466	335
% corn	*38*	*4*	*12*	*26*	*7*	*16*	*27*	*35*	*47*	*26*	*22*	*26*	*13*
Acres lespedeza	189	76	85	350	475	190	119	136	57	502	543	852	1018
% lespedeza	*49*	*63*	*71*	*56*	*33*	*39*	*42*	*65*	*38*	*44*	*49*	*49*	*40*
Acres corn+lespedeza	333	81	100	514	569	271	196	210	127	804	784	1318	1353
% corn+lespedeza	*87*	*68*	*83*	*82*	*39*	*54*	*70*	*100*	*85*	*70*	*70*	*75*	*53*
No. wintering quail	89	24	18	131	15	72	32	18	25	147	22	278	37
% wintering quail	*61*	*16*	*12*	*89*	*11*	*45*	*19*	*11*	*15*	*90*	*10*	*89*	*11*
Quail per 100 acres	23.3	20.0	14.3	20.8	1.0	14.3	11.4	7.7	16.7	12.9	2.0	16.9	1.5
1945 and 1946:													
Acres corn	232	19	15	266	172	181	135	106	100	522	388	788	560
% corn	*30*	*8*	*6*	*21*	*6*	*18*	*24*	*25*	*34*	*23*	*17*	*22*	*11*
Acres lespedeza	329	132	185	646	944	354	181	264	122	921	873	1567	1817
% lespedeza	*42*	*55*	*77*	*51*	*33*	*36*	*32*	*63*	*40*	*41*	*39*	*45*	*36*
Acres corn+lespedeza	561	151	200	912	1116	535	316	370	222	1443	1261	2355	2377
% corn+lespedeza	*72*	*63*	*83*	*72*	*39*	*54*	*56*	*88*	*74*	*63*	*56*	*67*	*47*
No. wintering quail	125	32	33	190	27	138	47	32	59	276	42	466	69
% wintering quail	*56*	*13*	*17*	*85*	*15*	*45*	*14*	*11*	*19*	*89*	*11*	*87*	*13*
Quail per 100 acres	16.3	13.4	13.2	15.1	0.9	13.7	8.3	7.2	19.7	12.1	1.9	13.6	1.4

* Other parts of the area, not in the major occupied ranges.
** *I.e.*, fencerows containing suitable winter cover.

30 per cent of the West Ashland area and four tracts comprising 51 per cent of the New Salem area. These are numbered in Table 3. The table summarizes the principal conditions found on each range.[2]

DISCUSSION

On each area there is approximately 0.6 mile of fencerow per 100 acres, with vegetation adequate for winter quail cover. Most of the birds have been found here.

It is clear from Table 3 that the winter quail range is characterized by a high proportion of Korean lespedeza (*Lespedeza stipulacea*) and corn, plus a high degree of interspersion of fencerows useful as cover. On comparing the occupied ranges with the remaining lands within the study areas, we find that they contain, per unit of area, more than three times as much fencerow cover, 50 per cent more corn, 25 per cent more lespedeza, and nearly nine times as many quail. Lespedeza and/or corn as winter food and fencerow cover seem here to be inseparable on winter quail range. No birds were found on parts of the areas where either was absent. Moreover, the ranges with the greatest increase in proportion of lespedeza showed the greatest increase in winter population, and the only two

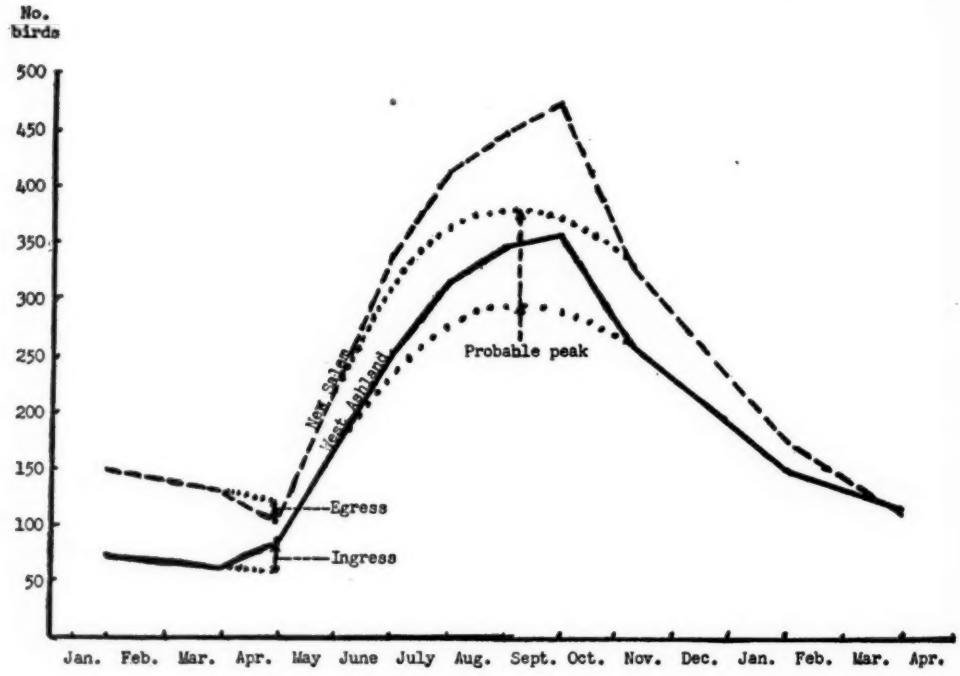

FIG. 1.—Population trends.

[2] The term "winter range" is here used to denote a unit of land occupied by one or more coveys.

ranges on which there was a decrease in winter population showed a decrease in proportion of lespedeza. Therefore lespedeza may be even more important than corn in winter in this region.

Korschgen (1947) has found that in Missouri Korean lespedeza is the most important fall and winter food of quail. This is also true of other lespedezas in the South (Cady ,1946; Davison, 1942, 1945; Gray, 1940; Johnson, 1940; Martin, 1935; Pearson, 1943; Ruggles, 1940; Stoddard, 1931: 136). In the northern states of the Corn Belt, where lespedeza does not thrive so well, corn has been found to be the most important winter food (Errington, 1930, 1931, 1933b, 1939; Hicks, 1932). Korschgen (*loc. cit.*) found corn ranking second in importance in Missouri. Degarmo (1943) found lespedeza and corn the most important winter foods in West Virginia. The value of Korean lespedeza and yellow corn as winter foods may be associated with their high Vitamin A content, especially in winter when other sources are scarce. Both are known to be high in Vitamin A content (Nestler, 1946; letter, April 1947).

A larger acreage is classified as winter range on the New Salem area (51 per cent) than at West Ashland (30 per cent), but the latter ranges carry a higher density of birds (West Ashland —15.1 birds per 100 acres, New Salem —12.1 birds per 100 acres). This superiority appears to be associated with higher proportions of lespedeza, corn, and fencerow cover. One may also explain on this basis the increase in carrying capacity on the West Ashland ranges from the first winter to the second, except that fencerow cover remained unchanged. On Range 1 (West Ashland), where the greatest increase occurred, 62 per cent of the areas that were fallow during the first winter were in corn or lespedeza during the second; corn and lespedeza together increased from 59 per cent to 87 per cent. This was important in itself; also, it produced more interspersion of these crops with existing fencerow cover.

Grazing of lespedeza and stalk-fields is detrimental to winter food and cover and makes the area unattractive to wintering quail. This has been mentioned by Stoddard (1931: 351–352) and Sanders (1934). An average of only 15 per cent of the corn and lespedeza on the quail ranges was grazed, while 48 per cent was grazed on the remaining lands. For example, a single 10-acre cornfield on the West Ashland area, neither grazed nor harvested at the time of the winter census, helped to support 15 per cent of the total quail population on the area.

The most luxuriant vegetative growth lespedeza, as well as heaviest seed-crop, was on limed land. When limed fields of lespedeza were within winter ranges, they were used constantly for food and covey roost-sites; judging from the success of lespedeza on unlimed soil, the cover would have been inadequate had the land not been limed. Liming may decrease the quantity of lespedeza required by a wintering bird, by improving its quality. In any case, it increases the quantity available.

There appears, then, to be a direct correlation between winter carrying capacity on the areas and interspersion of cover and high-quality staple foods, notably lespdeza and corn. Liming clearly helps. This is important in

managing quail on farmlands, because, as Davison (1942) has pointed out, efforts to increase the non-stapel preferred winter foods, as in the creation of artificial food patches, do not ordinarily fit into agricultural practices.

To summarize average winter conditions of food & cover on the ranges: About a mile (0.9 mile) of good fencerow cover adjoining 67 acres of lespedeza and corn, not more than 15 acres of which were grazed, supported 13.6 birds per 100 acres—one bird per 7.4 acres; this occurs on what is ordinarily mediocre range.

At least four practices in the interest of winter quail range are also consistent with sound farming in this region: (1) the use of lespedeza to increase soil fertility and decrease erosion; (2) preservation of fencerows and other cover as windbreaks and controllers of erosion; (3) conservative grazing; (4) liming. Davison (1941, 1942) has shown how such a union of interests can be established in the Southeast. According to Errington and Hamerstrom (1936): "The management of the bob-white may be closely linked with wise use of the land . . . The bob-white thrives best in agricultural communities, and its fortunes in the long run are essentially the fortunes of the soil. Management of this, as well as other wild species of similar requirements, may reasonably be dove-tailed into sound agricultural practice over wide areas of land."

SUMMARY

1. Quail populations on two farming areas in Boone County, Missouri, were studied from January 1, 1946, to April 1, 1947.

2. A larger acreage of winter quail range on the New Salem area accounted for a higher initial (1946) population of wintering birds here than on the West Ashland area.

3. Just before the nesting season, there was egress of birds from the New Salem area and ingress into the West Ashland area, showing the greater value (then) of the former as winter range and of the latter as nesting range.

4. The spring and summer populations of the two areas fluctuated together.

5. From the first winter to the second, the West Ashland population increased 106 per cent, that of New Salem only 13 per cent, indicating a large relative gain in carrying capacity on the former. This was principally associated with the planting of fallow fields to corn and lespedeza, which furnished a greater supply of staple foods of high quality adjoining good fencerow cover. These are the components of at least one type of good winter quail range. Four measures which contribute to the creation of such winter range—liming, conservative grazing, fencerow cover, and the use of Korean lespedeza—are entirely compatible with profitable farming in this part of Missouri.

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LATE-FALL AND EARLY-WINTER FOOD HABITS OF BOBWHITE QUAIL IN MISSOURI[1]

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The 52-day quail hunting season in Missouri spans a period of late fall and early winter. During the 1941 and 1942 seasons, 5,472 quail crops were received from hunters in all parts of Missouri, and the results of analysis of these crops will provide a key to management of the bobwhite's winter food supply.

A review of the literature dealing with the food habits of the bobwhite (*Colinus virginianus*) reveals that by far the most comprehensive studies to date have been in the southeastern part of its range.

Judd (1905) compiled data on the food habits of 918 quail from 21 states, the District of Columbia, Canada, and Mexico. Handley (Stoddard, 1931) made analyses of 1,569 crops from the Atlantic and Gulf Coastal Plain. Martin (1935) compiled a list of the more important quail food plants of the southeastern states as revealed by more than 2,000 records. Errington (1939) discussed winter foods used by the bobwhite in Wisconsin. Gray (1940) studied 440 bobwhite quail "stomachs" from the Black Belt Soil Province of Alabama. Johnson (1940) made a study of 1,835 quail crops collected during three years from eleven counties of northern Mississippi. Davison (1942) listed 130 groups, mostly plants, which had contributed one per cent or more of the contents of 5,189 crops collected from the southeastern United States. Lett and Pearson (1942) studied 611 bobwhite quail crops collected from the Piedmont Plateau of Alabama; and Pearson and Howell (1943) compiled data from 208 crops from the Limestone Valleys of Alabama. Cady (1944) collected 552 quail to study the effect of abandonment of farmland on the food of quail in the Norris Reservoir area of eastern Tennessee. These studies show that the bobwhite's fall and winter diet consists largely of vegetable matter. Similar results were obtained by Baldwin and Handley (1946) who studied 495 quail crops from Virginia. In only two of the above reports did animal matter constitute more than two per cent, by volume, of the diet.

Land Types of Missouri

This study includes material from all parts of the state of Missouri, which lies in the west-central portion of the bobwhite range recorded by Chapman (1940).

For purposes of this study, the eight major regions designated by Bennitt and Nagel (1937) were first recognized

[1] Contribution from the Missouri Cooperative Wildlife Research Unit, U. S. Fish and Wildlife Service, Wildlife Management Institute, Missouri Conservation Commission, and the University of Missouri cooperating. Assistance with identification of food items was given by Dr. Alec C. Martin, Lawrence W. Saylor, and Robert T. Mitchell.

and, to facilitate handling of the data, each was bounded by county lines: Northeastern River-breaks, Northern Riverbreaks, Northwestern Prairie, Western Prairie, Western Ozark Border, Northern and Eastern Ozark Border, Ozark Plateau and Mississippi Lowlands (Figure 1). In addition, Figure 1 shows the number of crops received from each of the 102 counties from which material was received during the two years of the study.

Palmer and Steyermark (1935) recognized three physiographic and plant regions in the state; Prairie region, Ozark region, and the Southeastern lowlands. A second analysis of the data was made, using the three physiographic and plant regions as a basis. These regions were also bounded by county lines, as shown in Figure 1.

Table 1 shows the size of the region and the number and distribution of crops received from each. Crops from the Northeastern Riverbreaks region constituted the largest sample, while the Northwestern Prairie region was the most poorly represented.

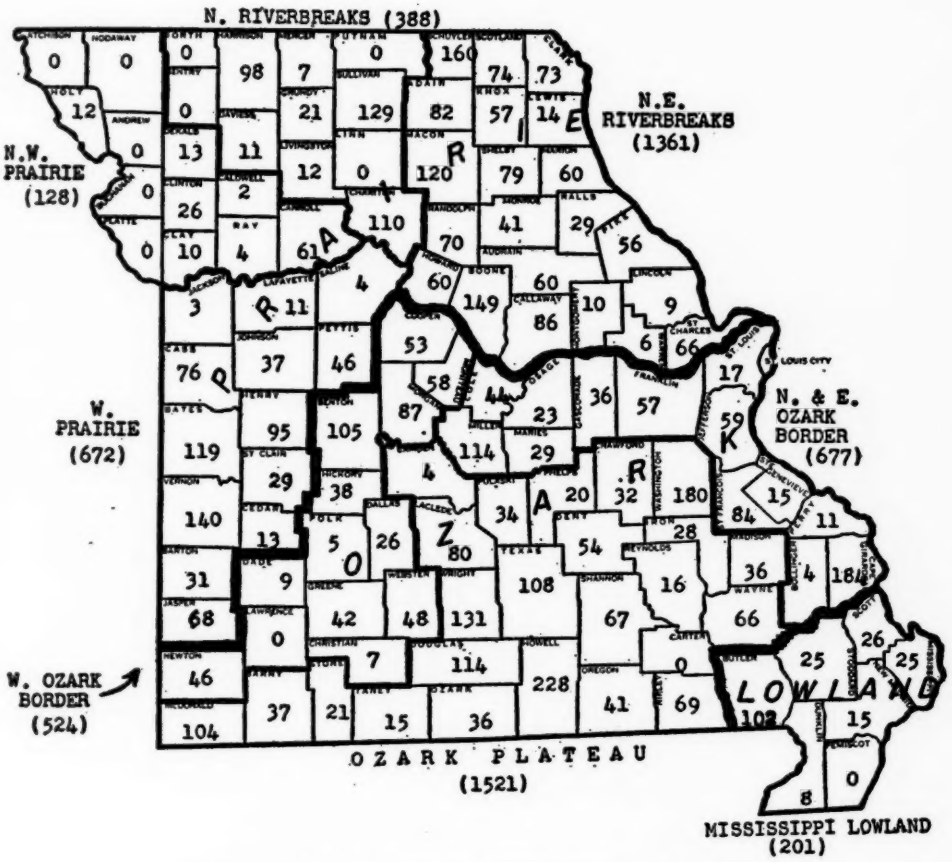

FIG. 1.—Distribution of quail crops by county and region.

TABLE 1.—REGIONAL SIZE AND NUMBER OF QUAIL CROPS

Region	Area*	Crops Received	
	(Sq. mi.)	No.	No./10 Sq. mi.
Northeastern Riverbreaks	11,745	1,361	1.17
Northern Riverbreaks	6,017	388	0.64
Northwestern Prairie	6,091	128	0.21
Western Prairie	9,046	672	0.74
Western Ozark Border	7,494	524	0.70
Northern and Eastern Ozark Border	7,422	677	0.91
Ozark Plateau	17,363	1,521	0.88
Mississippi Lowlands	4,092	201	0.49
Entire State	69,270	5,472	0.79

* From figures in Official Manual, State of Missouri, 1945–1946.

PROCEDURE

A list of Missouri quail hunters was available in connection with studies previously conducted at the Missouri Cooperative Wildlife Research Unit. A selected group was requested to save and submit crops of all quail killed. Approximately 150 hunters submitted 2,205 crops from 81 counties during the 1940 open season (November 10 through December 31). During the 1941 season, 230 cooperators sent in 3,267 crops from 93 counties.

All crops were numbered, catalogued, and stored dry in brown Kraft No. 3 coin envelopes in an air-tight chamber, with paradichlorobenzene as an insect repellent. They were still well preserved when the investigator returned from the Army four years later.

The equipment included: a 10x binocular dissecting microscope; Petri dishes; scalpel; screen sieves with 14, 16, 18, and 32 meshes per inch; forceps; 1, 5, and 10 cc. glass cylinders calibrated to 0.1, 0.1, and 1.0 cc., respectively; small tin scoop; wood or glass rods; glass vials; No. 8 lead shot, for use on the measurement of large seeds by the displacement method; and the University's collection of seeds of Missouri plants.

All analyses were of the dry crop contents. The crop was opened and its contents emptied into a 14-mesh sieve over a Petri dish. By moderate shaking, the larger seeds were separated from the smaller. If the bulk of the seeds passing through the screen consisted of several species of different sizes, that portion was given a second screening through smaller mesh. Complete separation was then made by hand. At first, forceps were used, but experience showed that seeds could be separated more rapidly by use of a sclapel. When the separation was complete, the volume of each species was measured. Large seeds, such as those of corn, soybeans, cowpeas, which could not be measured accurately in the small cylinders, were measured by the displacement method, using No. 8 lead shot as a medium. This involved the mixing of a known volume of lead shot with the large seeds and measuring the bulk. The shot filled what would otherwise have been air spaces; subtracting the known volume of shot from the total volume then gave a measurement for large seeds comparable in accuracy to that for smaller items.

Amounts too small for accurate measurement with the graduated cylinder were estimated as to size by sight, *e.g.* approximately 100 seeds of common ragweed constitute 1.0 cc. Thus, food items the size of a single ragweed seed were listed as 0.01 cc., those with equivalent size of two ragweed seeds as 0.02 cc., etc. This commonly involved only items of 0.01–0.05 cc. Items comprising less than 0.01 cc. were listed as "traces."

required to obtain a valid sample, tabulations were made, using 1,200 crops received from the Northeastern Riverbreaks region. The results are presented in Table 2.

Compilations were first made with occurrence as a basis. Thus the figures in the first line of Table 2 represent 1/24, 1/12, $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{3}$, and $\frac{1}{2}$ of the 1,200 crops. The lots were selected by first taking every 24th record to obtain 50. To these were added each 12th record

TABLE 2.—SPECIES FOUND IN PROGRESSIVELY LARGER SAMPLES OF QUAIL CROPS

Number of Crops	50	100	200	300	400	600	1,200
Total plant species found	39	58	86	92	102	128	165
% of total species found	*23.6*	*35.2*	*52.1*	*55.8*	*61.8*	*77.6*	*100*
% of total volume represented	*92.8*	*97.1*	*98.8*	*99.5*	*99.7*	*99.7*	*100*

All crops were subjected to complete analysis, regardless of their contents. It was found that, with experience, an average of seven to eight crops could be analyzed in an hour, although some difficult samples required an hour or more each.

The contents of 3,431 crops collected during November totaled 8,943.89 cc., or 2.6 cc. per crop. The contents of 2,041 crops collected during December totaled 6,565.26 cc., an average of 3.2 cc. The entire 5,472 crops contained 15,509.15 cc., an average of 2.8 cc. per crop. Empty crops were included in the total numbers; eliminating them would have increased the average figure by about 0.1 cc. per crop. The amount of food in a crop varied from none to 24.5 cc.

THE SAMPLE

In order to learn the number of crops to obtain 100; then each 6th to obtain 200; and so on. The total number of species represented was found to increase irregularly with the increase in number of records included, without reaching a maximum. By using occurrence as a basis, all species were represented as of equal importance, items occurring only once having the same significance as those occurring often. Moreover, items of low frequency were often missing from a small sample. On the basis of occurrence of food items, no conclusion could be drawn concerning the number of crops required to represent the food habits of quail in a region, since 300 crops revealed only about half, and 600 crops only about three-fourths, of the total species utilized by quail in this region.

The same data were analyzed using volume instead of occurrence. The total volume of items represented was then

determined as a percentage of the total food contents of all crops from the region. Thus, as shown in the third line of Table 2, the 39 food items found in the first 50 crops examined were those which made up 92.8 per cent of the total contents of 1,200 crops. The 58 items found in the first 100 crops included the food items which accounted for all but three per cent of the total, while 200 crops included all items making up nearly 99 per cent of the diet, as indicated by the 1,200 crops. More crops added little to the data. It is concluded, therefore, that a minimum of 100 crops should be obtained from a large area of similar plant growth in order to be representative, while 200 or more are preferable.

RESULTS

The results of this investigation are shown in tabular form for each major region and for the State as a whole. Food items are listed in order of importance by volume.

Seasonal percentages by volume are shown in Table 3 for the principal food items in each region. Table 4 shows percentages, by volume and by occurrence, for each month and for the entire season.

Volume-percentages were obtained by dividing the total volume of a specific item by the total vegetable, animal, and mineral content of all crops from the region. This method avoids the error produced by calculating volume-percentages for individual crops and adding to gain the total, as pointed out by Davison (1940). Occurrence figures were obtained by dividing the total number of crops in which a specific item occurred by the total number of crops from the region. All were carried to tenths of one per cent.

Summaries of plant and animal foods at the end of Table 4 were derived by adding the volume-percentages listed. The remaining percentages were composed of numerous items comprising less than 0.1 per cent of the total volume.

The term "group" refers to the smallest taxonomic group which could be identified. Thus, identification of plants was usually to species, that of insects and other animals to family. However, generic names for plants and order or class listings for animals were occasionally used, each constituting a "group."

Data presented in Table 3 reveal a distinct similarity in the feeding habits of quail from the Riverbreaks and Prairie regions, the Ozark and Ozark Border regions, and the Mississippi Lowlands. Considering the five principal foods, Korean lespedeza ranked low in the four Prairie regions and the Lowlands, but very high in the Ozark regions. Corn ranked high in the Prairie and Lowlands regions, and low in the three Ozark regions. Common ragweed was taken in quantity throughout the State, except in the Lowlands. Sorghum ranked high in the Prairie regions, but generally low in the Ozark and Lowlands regions. Oak mast was utilized in great quantity in the Lowlands, medium quantity in the Ozarks, and was little used in the Prairie regions. For this reason, only the three general regions—Prairie, Ozark, and Lowlands—designated by Palmer and Steyermark (1935), will be discussed.

PRAIRIE REGION

In general, the Prairie Region is characterized by soils of medium to high fertility, and level to undulating topography, broken by many tributaries of the Missouri and Mississippi rivers. Most of the region north of the Missouri River is glacial in origin, while that portion south of the river is unglaciated. The region is highly developed agriculturally. The prairie and valley soils are all under cultivation, while the river hills are mainly used as pasture. Farming practices are largely based upon the production of livestock. Corn, oats, soybeans, lespedeza, and the various grasses are the important crops (Krusekopf, 1945).

It was not surprising to find the seeds of cultivated plants predominating in

TABLE 3.—FORTY PRINCIPAL LATE-FALL AND EARLY-WINTER MISSOURI QUAIL FOODS

(Items are listed in order of importance, by volume. Figures are percentages, by volume. Figures below 1.0 per cent omitted.)

Food Items	Region							
	Prairie				Ozark			Lowland
	Northeastern Riverbreaks	Northern Riverbreaks	Northwestern Prairie	Western Prairie	Western Ozark Border	Northern and Eastern Ozark Border	Ozark Plateau	Mississippi Lowlands
No. of Crops Examined	1,361	388	128	672	524	677	1,521	201
Lespedeza stipulacea (Korean Lespedeza)	8.0	4.7	3.2	9.4	23.9	29.2	24.5	5.9
Zea mays (Corn)	30.8	38.1	45.3	12.3	8.6	8.7	5.0	27.4
Ambrosia artemisiae folia (Common Ragweed)	12.5	10.1	14.8	13.5	10.8	10.2	15.5	3.3
Sorghum vulgare (Sorghum Cane)	16.6	26.3	15.9	28.4	12.5	3.0	4.1	3.8
Quercus spp. (Oaks)	4.8	5.3	1.1	2.5	8.4	6.8	8.6	18.1
Sassafras albidum (Sassafras)	—	—	—	—	3.0	2.6	6.5	4.9
Glycine max (Soy Bean)	5.6	3.3	1.7	—	—	2.2	—	12.1
Desmodium spp. (Beggar's Ticks)	2.3	—	—	—	3.6	2.3	3.5	—
Strophostyles pauciflora (Small Wild Bean)	2.1	—	—	3.2	2.1	2.7	1.3	—
Croton monanthogynus (Croton)	—	—	—	—	2.0	1.1	4.0	—
Setaria lutescens (Yellow Foxtail Grass)	1.6	—	—	2.0	1.4	—	2.1	—
Strophostyles helvola (Trailing Wild Bean)	2.8	—	—	2.3	1.6	—	—	—
Fraxinus spp. (Ashes)	1.0	—	—	—	1.9	3.0	1.4	—
Lespedeza striata (Japanese Clover)	—	—	—	—	—	1.5	2.5	—
Croton capitatus (Hogwort)	—	—	2.9	2.8	1.2	1.2	1.1	—
Triticum aestivum (Wheat)	—	—	1.2	—	—	3.3	—	—
Crotonopsis elliptica (Crotonopsis)	—	—	—	—	—	2.4	1.5	—
Ambrosia bidentata (Lanceleaf Ragweed)	—	—	—	—	1.3	—	—	—
Bidens spp. (Beggar-ticks)	—	—	1.0	2.2	—	—	—	—
Vitis spp. (Wild Grapes)	—	—	—	1.3	1.0	—	—	—
Ambrosia trifida (Horse-weed)	1.2	1.8	1.2	—	—	—	—	—
Croton glandulosus (Croton)	—	—	—	1.3	—	1.3	—	1.8
Vigna sinensis (Cow Pea)	—	—	—	—	—	—	—	7.5
Rhus glabra (Smooth Sumach)	—	—	—	1.3	—	—	—	—
Rhus copallina (Dwarf Sumach)	—	—	—	—	2.0	—	—	1.0
Perilla frutescens (Beef-steak Plant)	—	—	—	—	—	—	1.5	—
Quercus stellata (Post Oak)	—	—	—	—	3.0	—	—	—
Panicum dichotomiflorum (Fall Panicum)	—	—	—	—	—	1.0	—	—
Polygonum scandens (False Buckwheat)	—	2.3	—	—	—	—	—	—
Avena sativa (Oats)	—	—	—	1.1	—	—	—	—
Setaria italica (Italian Millet)	—	—	—	1.9	—	—	—	—
Maclura pomifera (Osage Orange)	—	—	—	1.0	—	—	—	—
Helianthus spp. (Sunflowers)	—	—	—	—	—	—	—	1.4
Bumelia lanuginosa (Chittim-wood)	—	—	—	—	—	1.3	—	—
Cannabis sativa (Hemp)	—	—	4.6	—	—	—	—	—
Quercus palustris (Pin Oak)	—	—	—	—	—	—	—	1.3
Liquidambar styraciflua (Sweet Gum)	—	—	—	—	—	—	—	1.1
Acrididae (Short-horned Grasshoppers)	—	—	—	—	1.1	—	—	—
Pentatomidae (Stink Bugs)	—	—	—	—	—	—	—	1.1
Carabidae (Ground Beetles)	—	—	—	—	—	1.0	—	—
Total	89.3	91.9	92.9	86.5	89.4	84.8	83.1	90.7

TABLE 4.—STATEWIDE SUMMARY OF PRINCIPAL LATE-FALL AND EARLY-WINTER MISSOURI QUAIL FOODS

(Items are listed in order of importance by volume.)

Food Items	November (3,431 Crops)		December (2,041 Crops)		Season (5,472 Crops)	
	% by Volume	Occurrence	% by Volume	Occurrence	% by Volume	Occurrence
Lespedeza stipulacea (Korean Lespedeza)	12.1	39.5	24.5	53.6	17.4	44.8
Zea mays (Corn)	15.8	21.1	18.1	24.0	16.8	22.2
Ambrosia artemisiaefolia (Common Ragweed)	14.4	38.8	10.4	33.0	12.7	36.6
Sorghum vulgare (Sorghum Cane)	11.5	13.9	12.9	12.5	12.1	13.1
Quercus spp. (Oaks)	7.7	13.4	5.2	10.5	6.6	12.1
Sassafras albidum (Sassafras)	3.0	4.6	2.8	4.9	2.9	4.7
Glycine max (Soy Bean)	2.3	4.9	3.0	6.1	2.6	5.4
Desmodium spp. (Beggar's Ticks)	2.5	8.4	2.2	14.5	2.3	10.7
Strophostyles pauciflora (Small Wild Bean)	2.1	19.8	1.4	14.7	1.8	17.9
Croton monanthogynus (Croton)	2.1	10.5	1.0	9.1	1.7	10.0
Setaria lutescens (Yellow Foxtail Grass)	2.1	14.2	0.7	8.9	1.5	12.2
Strophostyles helvola (Trailing Wild Bean)	1.1	5.4	1.8	6.6	1.4	5.9
Fraxinus spp. (Ashes)	0.9	3.5	1.9	5.5	1.3	4.2
Lespedeza striata (Japanese Clover)	0.9	11.9	1.3	17.4	1.1	14.0
Croton capitatus (Hogwort)	1.1	5.7	1.0	5.3	1.1	5.6
Triticum aestivum (Wheat)	1.0	3.0	0.8	3.2	0.9	3.1
Crotonopsis elliptica (Crotonopsis)	1.2	4.3	0.3	2.9	0.8	3.8
Ambrosia bidentata (Lanceleaf Ragweed)	0.9	7.4	0.5	6.5	0.7	7.1
Bidens spp. (Beggar-ticks)	0.9	8.2	0.2	4.9	0.6	7.0
Vitis spp. (Wild Grapes)	0.8	4.4	0.4	3.5	0.6	4.1
Ambrosia trifida (Horse-weed)	0.6	4.1	0.3	3.7	0.6	3.9
Croton glandulosus (Croton)	0.7	3.8	0.4	1.8	0.6	3.1
Vigna sinensis (Cow Pea)	0.6	0.8	0.5	0.9	0.6	0.9
Rhus glabra (Smooth Sumach)	0.7	3.6	0.3	3.2	0.5	3.4
Rhus copallina (Dwarf Sumach)	0.2	1.1	0.8	3.0	0.5	1.8
Perilla frutescens (Beef-steak Plant)	0.5	1.1	0.4	0.7	0.5	0.9
Quercus stellata (Post Oak)	0.4	0.5	0.6	0.6	0.5	0.5
Panicum dichotomiflorum (Fall Panicum Grass)	0.6	12.1	0.1	6.0	0.4	8.0
Polygonum scandens (False Climbing Buckwheat)	0.4	5.1	0.4	5.0	0.4	5.1
Avena sativa (Oats)	0.5	2.1	0.1	1.5	0.4	1.9
Cornus florida (Flowering Dogwood)	0.3	0.9	0.4	0.9	0.4	0.9
Amphicarpa bracteata (Hog Peanut)	0.4	4.1	0.2	3.3	0.3	3.8
Setaria italica (Italian Millet)	0.4	0.6	0.2	0.9	0.3	0.7
Leaf material	0.1	4.1	0.3	14.8	0.2	8.1
Galactia volubilis (Milk Pea)	0.2	3.0	0.2	3.5	0.2	3.2
Impatiens pallida (Touch-me-not)	0.1	1.5	0.3	1.1	0.2	1.3
Maclura pomifera (Osage Orange)	0.3	1.0	0.1	0.9	0.2	1.0
Helianthus spp. (Sunflowers)	0.3	1.3	trace	0.5	0.2	1.0
Bumelia lanuginosa (Chittim-wood)	0.3	0.8	0.1	0.2	0.2	0.6
Diospyros virginiana (Persimmon)	0.4	0.7	trace	0.3	0.2	0.6
Robinia pseudo-acacia (Black Locust)	0.3	0.6	trace	0.3	0.2	0.5
Paspalum ciliatifolium (Fringeleaf Paspalum)	0.1	7.4	trace	7.7	0.1	7.5
Panicum capillare (Witch Grass)	0.1	7.7	0.1	6.1	0.1	7.1
Digitaria sanguinalis (Crab Grass)	0.1	5.6	trace	3.9	0.1	5.0
Cassia fasciculata (Partridge Pea)	0.1	4.1	0.1	5.3	0.1	4.6
Lespedeza spp. (Lespedezas)	0.1	3.6	0.1	6.4	0.1	4.6
Polygonum pensylvanicum (Pennsylvania Smartweed)	0.2	3.4	0.1	4.3	0.1	3.7
Physalis spp. (Ground Cherries)	0.2	4.7	0.1	1.7	0.1	3.6
Polygonum spp. (Smartweeds)	0.1	2.1	trace	2.5	0.1	2.3
Cuphea petiolata (Clammy Cuphea)	0.1	1.7	trace	2.6	0.1	2.0
Digitaria ischaemum (Small Crab Grass)	0.2	1.5	trace	0.6	0.1	1.2
Viola spp. (Violets)	0.1	1.4	trace	0.8	0.1	1.2
Strophostyles umbellata (Pink Wild Bean)	0.1	1.0	trace	1.2	0.1	1.1
Steria viridis (Green Foxtail Grass)	0.1	1.0	0.1	0.6	0.1	0.8
Undetermined Plant Material	trace	0.8	0.1	0.8	0.1	0.8
Isanthus brachiatus (False Pennyroyal)	0.1	0.8	trace	0.6	0.1	0.7
Sporobolus neglectus (Puffsheath Dropseed Grass)	trace	0.2	0.2	1.3	0.1	0.6
Sorghum halepense (Johnson Grass)	0.1	0.8	trace	0.1	0.1	0.6
Commelina spp. (Day-flowers)	0.1	0.6	0.1	0.5	0.1	0.6
Cornus spp. (Dogwoods)	0.2	0.7	trace	trace	0.1	0.5
Commelina erecta (Day-flower)	0.1	0.4	0.1	0.4	0.1	0.4
Secale cereale (Rye)	0.1	0.3	trace	0.2	0.1	0.3
Ampelopsis cordata (False Raccoon Grape)	trace	0.1	trace	0.6	0.1	0.3
Croton spp. (Croton)	trace	0.3	0.2	trace	0.1	0.2
Cannabis sativa (Hemp)	0.1	0.1	0.2	0.1	0.1	0.1
Cornus obliqua (Swamp Dogwood)	0.1	0.1	0.0	0.0	0.1	0.1
TOTAL of 66 Plant Foods	95.9		97.9		97.0*	
Acrididae (Short-horned Grasshoppers)	1.2	9.6	0.2	4.7	0.8	7.7
Carabidae (Ground Beetles)	0.8	14.1	0.4	11.4	0.6	13.1
Pentatomidae (Stink Bugs)	0.4	7.2	0.1	2.5	0.3	5.4
Cicadellidae (Leaf Hoppers)	0.1	5.5	trace	3.5	0.1	4.8
ARANEIDA (Spiders)	0.1	5.7	0.1	4.6	0.1	5.3
LEPIDOPTERA (Moths and Butterflies)	0.1	3.3	0.1	5.3	0.1	4.0
TOTAL of 6 Animal Foods	2.7		0.9		2.0**	
TOTAL PLANT	96.6		98.9		97.6	
TOTAL ANIMAL	3.4		1.1		2.4	
TOTAL GRAVEL	trace		trace		trace	
TOTAL CONTENTS	100.0		100.0		100.0	

* An additional 0.6 per cent was comprised by 236 plant groups which occurred as traces.
** An additional 0.4 per cent was comprised by 64 animal groups (mostly insects) which occurred as traces.

the crops of quail. Large scale production of corn makes that item readily available as quail food; it was taken often and in great quantity. Corn comprised more than one-fourth (28.2 per cent) of the total volume of food. Sorghum cane ranked second as a quail food in the region, and comprised more than one-fifth (20.7 per cent) of the total. Common ragweed was third in importance. This species thrives naturally in the aftermath of small grain crops, and is commonly and generally distributed throughout the region. Korean lespedeza and oak mast were fourth and fifth in importance. Other important foods are listed in Table 3.

Quail from the Prairie Region were found to have eaten 204 kinds of plant and 65 kinds of animal food. Of this number, 13 plant items comprised 1.0 per cent or more of the total volume, while 152 plant and 60 animal groups constituted less than 0.1 per cent each.

OZARK REGION

The Ozark Region displays rolling topography on the western border, where the soils are light, gravelly, and from moderate to good in productivity. Diversified farming is carried on and dairying is a major industry.

The northern and eastern part of the Ozark Region is hilly and somewhat more dissected than the western part. The soils are of medium to low productivity, and erosion is active everywhere. Much of the land is used for pasture and woodlots, because it is too steep for cultivation. General farming is the common practice, with wheat and corn the important crops.

The central part of the Ozark region is hilly, the soil light, shallow, rocky, and of low productivity. This combination of factors makes it impossible to utilize most of the land for agricultural purposes. More than 60 per cent of the area is forested. The cleared upland is used mainly for pasture, and lespedeza is the most important hay and pasture crop. The narrow creek bottoms are used for corn. Livestock is a major source of income, and the profits in farming are more limited than in any other part of the state (Krusekopf, 1945).

In accordance with the diversified type of farming and dairying, a departure from the trend of feeding habits found in more intensively cultivated regions was noted. Korean lespedeza has been extensively sown on the less productive soils and has shown a corresponding increase in importance as quail food. This single item accounted for more than one-fourth of the total volume of food taken in the region. Ragweed remained a favored quail food and was second in importance. The utilization of oak mast showed a significant increase, as compared with that in the agricultural Prairie Region. The smaller acreage of corn and sorghum was reflected in their lesser use by quail. While these items ranked fourth and fifth, respectively, in importance, their utilization was only approximately one-fourth that in the Prairie Region. The seeds and fruits of sassafras (*Sassafras albidum*), a woodland species common throughout the Ozarks, also were extensively used, and comprised nearly 5.0 per cent, by volume, of the total food. Other important species are listed in Table 3.

Quail in the Ozark Region were found to have eaten 251 plant and 66 animal

foods, a greater variety than was found in the Prairie Region. Only 16 of the 317 foods amounted to 1.0 per cent or more of the total volume, while 191 plant and 59 animal groups occurred only as traces.

MISSISSIPPI LOWLANDS

The Lowlands Region of southeastern Missouri is a level, alluvial plain, displaying a wide range of soil and farming conditions. The sandy loams along the Mississippi River are very rich in the production of cotton and corn. The dark, heavy soils of the south-central section are used for cotton and soybeans. The soils are as yet poorly developed for agriculture, because of deficient drainage. In general, the soils and agriculture of the Lowlands are characterized by their diversity (Krusekopf, 1945).

While cotton is a leading agricultural crop, no trace of the seeds was found in the 201 crops examined. Corn, on the other hand, accounted for more than one-fourth (27.4 per cent) of the food consumed. Oaks of various species were second, with soybeans (*Glycine max*) and cowpeas (*Vigna sinensis*) ranking third and fourth, respectively. Korean lespedeza ranked fifth and made up 5.9 per cent of the food. The last column of Table 3 contains a list of the more important species.

A total of 84 plant and 33 animal groups was found to have been eaten by quail in the Lowlands Region. Of this number, only 13 plant groups and one animal group were found in amounts constituting 1.0 per cent or more of the total volume, while 54 plant and 29 animal groups occurred only as traces.

DISCUSSION

Table 4 shows, in order of importance by volume, the most important items of food as determined by the analysis of 5,472 quail crops from 102 of Missouri's 114 counties. Percentages of each item are listed separately for November, December, and then combined for the season. Only the seasonal figures will be commented upon here.

It was found that certain plants ranked high in all regions. At least five were conspicuous: Korean lespedeza (*Lespedeza stipulacea*) and corn (*Zea mays*) ranked among the five most important items in all regions and, in the same order, were the two most important foods in the state-wide summary. Common ragweed (*Ambrosia artemisiaefolia*) ranked third and was among the five most important foods in seven of the eight regions. Sorghum cane (*Sorghum vulgare*) and oaks (*Quercus* spp.) ranked fourth and fifth and were important in five and four of the regions, respectively.

Sixty-five families, including 302 groups, of plants were identified. This number of plant groups (302) also included numerous kinds of green leaf material and root scales which were placed under a single heading (Leaf material). Plant galls, too, were listed under one heading, and one was provided for all unidentified plant materials.

In addition, 54 families in nine orders of insects, eight families in four classes and two orders of miscellaneous animals, and occasional fragments of bone egg-shell, and undetermined animal matter were included in the bobwhite's diet. No single item of animal food ac-

counted for as much as 1.0 per cent of the volume but, collectively, animal foods made up 2.4 per cent of the crop contents.

Considerable variation was noted in the importance of Korean lespedeza and common ragweed during the two seasons of the present study. For example, data previously compiled for 1940 alone showed common ragweed as the most important food, accounting for 20.4 per cent of the total volume. Korean lespedeza during the same year amounted to 16.4 per cent of the total and ranked third. During the second year of the study, Korean lespedeza ranked first, with 18.3 per cent by volume, while ragweed ranked fourth, with 6.7 per cent.

No satisfactory explanation was derived for the reversal in the degree of utilization of the foods mentioned above, unless attributable to decreased availability of ragweed caused by weather conditions during the second year. Figures obtained from the Extension Service, Agricultural Experiment Station, University of Missouri, reveal an approximately 33 per cent increase in acreage of Korean lespedeza from 1940 to 1941. The corresponding increased use by quail amounted to only 1.9 per cent, while use of common ragweed decreased 13.7 per cent. Insofar as could be determined, the growing seasons were equally favorable both years, except that an excessive amount of rainfall was recorded during September and October of the second year (more than five times normal in October 1941). Since common ragweed is a wind-pollinated plant, it is possible that the excessive rainfall, widely distributed in the State, prevented pollination and consequently curtailed the seed crop in 1941.

The findings in this study confirm the findings of authors who have investigated the food habits of quail in other parts of their range. Judd (1905), Handley (Stoddard, 1931), Martin (1935), Gray (1940), Davison (1942), and Pearson *et al* (a series, 1942–1945) found that the bulk of the bobwhite's food was made up of species from a few plant families. In Missouri, seven plant families contained all the late-fall and early winter foods comprising 1.0 per cent or more of the volume of the diet. Of these, the Gramineae were most important; 46 species (three of them important) supplied 33.1 per cent of all food consumed. The Leguminosae, most important in the southeastern states, ranked second in Missouri. This group was represented by 34 species and accounted for 28.4 per cent of the seasonal food, principally through six species. The Compositae, represented by 31 species, ranked third with 14.8 per cent, but only common ragweed was important. The Fagaceae were fourth in importance and accounted for 7.2 per cent of the food consumed. Other important families were the Euphorbiaceae, 4.3 per cent; Lauraceae, 2.9 per cent; and Oleaceae, 1.3 per cent. The last two families were important only in the Ozarks.

There was a pronounced scarcity of grit or gravel; it was found in only 184 crops (3.4 per cent of the 5,472 examined) and in very small quantities, rarely exceeding 0.05 cc. per crop. This seemed to confirm the findings of Nestler (1946), who concluded that hard seeds apparently can replace grit as grinding agents in the diet. Handley

(Stoddard, 1931) asserted that bobwhite quail consume little grit when hard seeds, such as those of loblolly pine or wild cherry, form main items in the diet.

SUMMARY

Data on the late-fall and early-winter food habits of the bobwhite quail in Missouri were procured from the analysis of the contents of 5,472 crops received during the hunting season, November 10–December 31, 1940 and 1941. Hunter-cooperators secured and submitted crops from 102 of Missouri's 114 counties.

1. Storage of dry crops in a paradichlorobenzene chamber proved a very satisfactory means of preserving study materials. Crops used in this study remained in a good state of preservation after five years of such storage.

2. To be representative, a minimum of 100 crops should be obtained from an area of similar plant growth; 200 or more are preferable.

3. The food habits of quail were found to be different in three general regions: Prairie, Ozark, and Lowlands.

4. Vegetable items of 302 species comprised 97.6 per cent of the food of quail during the hunting season, while 70 animal groups made up the remaining 2.4 per cent.

5. Only fifteen foods occurred as 1.0 per cent or more in the bobwhite's diet and comprised 83.3 per cent of the total. They were: Korean lespedeza, 17.4 per cent; corn, 16.8 per cent; common ragweed, 12.7 per cent; sorghum cane, 12.1 per cent; oaks, 6.6 per cent; sassafras, 2.9 per cent; soybean, 2.6 per cent; beggar's ticks, 2.3 per cent; small wild bean, 1.8 per cent; croton, 1.7 per cent; yellow foxtail grass, 1.5 per cent; trailing wild bean, 1.4 per cent; ash, 1.3 per cent; Japanese clover, 1.1 per cent; and hogwort, 1.1 per cent.

6. No single animal food made up as much as 1.0 per cent by volume during the period covered by this study.

7. During the two years of the study, ragweed dropped in importance from first place, with 20.4 per cent of the total food eaten, to fourth place, making up only 6.7 per cent of the diet. This decrease in utilization of ragweed the second year was believed due to a curtailed seed crop caused by excessive rainfall which prevented pollination.

8. During the second year, use of Korean lespedeza increased only 1.9 per cent, in spite of the fact that acreage grown increased by approximately 33 per cent.

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CATTLE ON GRIZZLY BEAR RANGE

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INTRODUCTION

Bear predation in the United States involves two kinds of bears, the grizzly (*Ursus horribilis*) and the black (*Ursus americanus*). Because the grizzly today occupies a restricted range and the black bear is widely distributed, most ideas about bear predation concern the latter. It appears from the information gathered by the author that the two species differ in their propensity for preying on cattle, so cannot be lumped together in considering the bear predation problem.

The grizzly has long been famous as a cattle killer, but except for a few incidents given by Seton (1929, Vol. II, p. 28) there is little information in the literature on the subject. The Alaska brown bear, closely related to the grizzly has been accused of killing cattle on Kodiak Island but a study made by Sarber (1939) showed that most of the cattle deaths were due to malnutrition and that the bears were largely feeding on carrion rather than on their kills. In this study a few deaths were attributed to the bears but the physical condition of the animals at the time of attack was not known to be normal.

In the area where the grizzly was

[1] Observations were made by the author, by Ranger Verland Taylor, who cooperated with him throughout the study, by O. J. Murie, and by the cowboys. At all times good cooperation was received from Supervisor Arthur Buckingham and his staff, herders, and cattlemen.

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observed, predation on cattle was rather consistent, while the information received in letters from range men indicates that black bear predation on cattle is highly sporadic. In a letter from a Regional Forester is this statement about the black bear: "The predation is mostly confined to sheep, although in one case . . . a calf was attacked. . . . The predation, so far as livestock is concerned, has always been spotted and occurs in unpredictable locations. It quite frequently happens that predation by bear is heavy in a certain area one year, and then for a number of years no losses occur." A district forest ranger in Wyoming mentions a number of cases of bear predation on sheep and then writes as follows about cattle: "No cattle have been killed by bear on this district for the last fifteen years."

A forest ranger in Colorado writes: "The killing of sheep by bear in this section is common, however I have had rare reports and in only one case have I ever found any cattle that I believed was killed by bear, although they work on nearly every carcass I find on the range, and for this reason one doubts most of the cattle killings reported for bear."

Another Forest Service ranger in Colorado, after describing the killing of a yearling steer, writes: "There are an average of three or four authenticated cases of predator bear killings on this district annually."

A hunter in Idaho, in writing about domestic sheep that the bear had killed, states: "As for how they kill cattle I have never had the experience for there are no cattle killing bear in this vicinity." Possibly where domestic sheep are found, they serve as a buffer for cattle since they are more readily taken by bears.

A Forest Service ranger in Colorado forwarded a letter from a stock man in which the black bear was accused of killing six cattle. The tenor of the letters received is much the same, the black bear occasionally kills cattle but the time and place are usually unpredictable.

Range men and oldtimers hold many shades of opinion on the subject of bear predation on cattle. This is to be expected, at least in the case of the black bear, because of the sporadic nature of its predation. One field man might happen to have seen several cases of predation, while another could easily have spent a lifetime on the range without seeing an unquestionable bear kill. A body of acceptable information has not accumulated on the subject. There have been so many misinterpreted cases, and the bear has been unjustly accused so often, that every reported incident is seriously doubted by experienced range men. A bear story ranks with the fish story so far as reliability is concerned. One experienced range man related that he had made over forty investigations of alleged bear kills without finding evidence in a single case to convict the bear.

An acquaintance cited a case, on which information is had from several sources. In a small area over fifty dead cattle presumably had died from larkspur poisoning. And bears had not yet fed on the carcasses at the time of his inspection. Later the herder found the carcasses, noted that bears had fed on them, and accused the bear of killing

the cattle. The author is personally familiar with a number of misinterpretations of this nature. The feeding on a carcass by bear is so commonly used as evidence that the bear has done the killing, that any reported bear-killing episode must necessarily be received with skepticism.

Observations on bear predation were made in Jackson Hole, Wyoming, more specifically on the Spread Creek and Black Rock Creek ranges in the mountain country of Teton National Forest. This is an excellent summer range, with many open parks along the streams and in the forests of lodgpole, douglas fir, spruce, fir, and aspen. About 1600 cattle (not counting the calf crop) for which grazing permits have been issued by the Forest Service, are brought onto the ranges in the middle of June. They gradually work up the stream bottoms until they reach the high divide in the Twogwotee Pass region. In the fall of the year the movement is reversed and by the last of October the cattle are again off the forest. There is relatively little herding, but salt is distributed over the range and a drift fence at the mouth of Flagstaff Creek keeps the cattle on Spread Creek from moving to the higher ranges before they are ready for use. At the proper time the gates are opened and the cattle drift up the creek bottoms to new grazing. Some of the cattle drift to the higher country of their own accord, many tarry and are driven up later.

On these ranges the black bear and the grizzly are both present, and, over a period of years, have been reported as preying on cattle. Considerable control of the bears has been practiced both officially and unofficially. In the early thirties an extensive trapping campaign is reported and in recent years there has been more moderate control officially and by the cattlemen. However in 1945 a cattleman stated that "we gave the bears *hell* two years ago" but the author was unable to ascertain how many bears were killed. Along with the killing of bears for control purposes there has been some hunting by sportsmen. It is extremely difficult to estimate the bear population on the area. In 1946 there were at least four adult grizzlies operating on the range. Black bears were not especially plentiful although tracks and an occasional bear were seen. Their tracks were seldom observed on the cattle trails where grizzly tracks were regularly noted.

The studies on bear predation here reported were made in 1945 and 1946. They were begun in the latter half of June about the time the cattle moved onto the Forest, and each year, due to another assignment, were terminated in early August. However the author was on the range at the time that most of the predation was taking place.

CATTLE LOSSES IN 1945

Among the 1648 cattle (not including the 1945 calf crop) reported on the Spread Creek, Black Rock Creek allotment, there were 25 known casualties. Of these four were due to unknown causes, 11 to disease or poisoning, and 10 to bear predation. There no doubt were other losses not discovered but it is thought that the majority of them were found. Figures for actual losses are usually not obtainable because most cattlemen do not keep an accurate check on their losses. On adjacent ranges which were not studied, a few

loss figures were supplied as follows: In 92 head grazing on Pacific Creek there were two losses, one due to poisoning, the other to an unknown cause. On Lava Creek where 245 cattle summered there were four losses, two of which were reported as bear kills. Of 891 cattle on the Moran allotment only one loss was reported. These cattle, in general, were ranging lower than the ones studied, which would suggest that they were on ranges on which grizzlies were scarcer, although this is not definitely known. Black bears would be expected to be about as numerous here as on the range studied.

Cattle on the range die from a number of causes. It is generally believed that the principal losses on Teton National Forest are due to larkspur poisoning. Small losses due to poisoning are apparently common, and occasionally there have been large losses. In the fall of 1941 it was reported that 107 cattle were found dead from poisoning on a Gros Ventre range. On this same range nine calves are reported to have died a few days after feeding on alkali mud. How many cattle die from disease no one knows.

The 25 known losses observed in 1945 on the Spread Creek-Black Rock Creek ranges are listed in three groups as follows: cause of death unknown, disease or larkspur poisoning, and bear predation.

CAUSE OF DEATH UNKNOWN

The cause of the death of four animals, a yearling and three calves, was not learned. Two of the calves died in a pasture on the lower margin of the range. They were assumed to be bear kills by the herder but the only evidence to support this view was the fact that the bears had fed on the carcasses. Calf droppings, typical of white scours, seen in the pasture, were suggestive. At the mouth of Flagstaff Creek a yearling and a calf had died but the remains were too fragmentary for a diagnosis. The herder called them bear kills. They may have been, for a little later some bear kills were found in this area but, on the other hand, some carcasses were found in the area which were not bear kills.

LOSSES FROM PLANT POISONING OR DISEASE

Eleven of the 25 losses were due to disease or larkspur poisoning. The post mortem appearances of larkspur poisoning and some diseases are so similar that it is not always possible to differentiate between the two categories in the field. The ages of the 11 animals were as follows: One calf, five yearlings, two two-year-olds, one three-year-old, and two adult cows. Two of the deaths were definitely due to disease rather than plant poisoning. One of these, a two- or three-months-old calf, had a congestion of pus in the lungs. In this area at the time there were small bloody droppings which indicated that at least another calf was ailing. A yearling heifer, noted on July 26, had definitely died from disease. The flesh of the neck and shoulder was highly inflamed. There had been much internal bleeding and the lungs were full of blood. In the liver there were numerous rounded, hard, cheesy yellow balls about one inch in diameter and the liver adhered to lesions in the omentum. There were lesions in the stomach wall, one of them almost penetrating it. The flesh of some

of the other animals was highly inflamed and in some cases there was a focal point, made up of a yellowish, gelatinous substance. The lungs were sometimes full of blood and a bloody liquid was at times in the chest cavity. A yearling died from an injured shoulder which was greatly swollen, but showed no external bruises. For the most part the animals were in good flesh.

LOSSES ATTRIBUTABLE TO BEARS

Relatively few range men have observed incidents in which there was definite proof that a bear had killed cattle. Because so few have been described and because it seems especially important to give the circumstances on which judgments were based, each case is described in some detail.

There were 10 casualties on the Black Rock-Spread Creek range which were attributed to bear predation. Nine of the remains were examined by the author, and the tenth was described to him by Ranger Verland Taylor, a trustworthy observer who was with the writer in the examination of several of the other cases. It is thought, because of general circumstances, that the grizzly rather than the black bear, killed the cattle, but there is definite proof of this in only 3 cases, and fairly good proof in two cases.

Cases I and II. On July 13 at 1:45 P.M. over a hundred cows on the bottoms along Buffalo Fork were in a noisy turmoil. The vanguard was met at the edge of the woods near Black Rock Ranger Station. There were a number of lost calves, and many mothers were bawling loudly. Realizing that something had caused this troubled activity the writer moved along slowly just inside the margin of the forest. When about a third of a mile from where he first met the cattle, ravens were seen ahead of him and one in particular was noticed with a piece of red meat in its bill flying in a direct line over the tree tops. Looking back along the line of flight a raven or two was noticed on a knoll under some lodgepole pines and aspens at the edge of the forest. There, the warm carcasses of a yearling heifer and a calf were found. While the carcass of the yearling was being examined, 15 or 20 nervous cattle approached curiously to watch. The yearling lay 40 yards from a salt lick and the calf was 70 yards from the yearling.

The observer hurried to camp for cameras and returned to the carcasses with Ranger Verland Taylor. They carefully examined the animals where they lay, then partly skinned them out and looked at the internal organs.

The yearling lay on its side on a gentle slope. The brisket was exposed for a length of 20 inches and the flesh on it and down over the adjoining ribs had been eaten. There was a large opening into the abdominal cavity through which the stomach and intestines had been cleanly removed. After their removal the carcass had been pulled down the slope about 10 feet. The liver, lungs, and heart were in place. Dorsally on the base of the neck were tooth wounds, two on one side and five on the other, which were undoubtedly made by a bear. The tooth wounds were about one-half inch in diameter, large enough so that an entire finger could be inserted. The two on one side were 2 and one-quarter inches apart; the five on the other side from 1 inch to 3 and one-

half inches apart. All these tooth wounds appeared to have been made by the canine teeth. One set of teeth had apparently remained fixed and the other set shifted some in the biting. The dorsal processes of two cervical vertebrae had been severed. There were five shallower tooth marks around one eye; one of the teeth had crushed part of the zygomatic arch. Deep tooth wounds were also present on both sides of the vertebrae in the lumbar region. One of the teeth had penetrated the dorsal process of a vertebra. The bites here were obviously about as damaging as they were on the neck and probably had a paralyzing effect on the animal. (A ranger familiar with cattle said that on several occasions he had struck a cow on the small of the back with a board and temporarily paralyzed her. Once, in a tight spot in a corral he disposed of an elk in the same way.) The bite wounds had bled a little, more on the neck than on the back.

It appeared that the yearling may have struggled some after first being attacked. For a distance of eight yards there were drag marks and blood on the ground and sagebrush. Between this scuffled area and the spot where the animal had finally fallen, a distance of ten yards, there were no marks, indicating that the animal had run a short distance before being brought down.

The yearling was fat. The internal organs seemed healthy except for the lungs which had a few scattered nodules that contained pus in the tissue. The lung infection seemed too slight to have reduced the vigor of the animal, although there is the possibility that the infection, although slight itself, might have indicated the presence of a serious ailment. However it can probably be assumed that the animal was strong. The contents of the stomach consisted of grass and a little willow. Larkspur was not abundant in the area so it seemed doubtful that the animal was affected by poisoning.

The wounds on the calf were similar to those on the yearling. Here also the meat on the brisket had been eaten and the stomach and intestines cleanly removed through a ventral opening into the abdominal cavity. There were deep, crushing bites in the neck near the skull and in the lumbar region of the back. The teeth had penetrated the axis vertebra and almost severed the spinal cord. The atlas was torn loose from its articulation with the skull. On the shoulder was what appeared to be a claw scratch. The heart and lungs appeared normal; the liver had been eaten. The stomach contained grass and a trace of willow. This calf, about two and one-half or three months old, was fat and apparently in good health.

The two animals had been killed about noon, for the tooth wounds felt hot to the fingers when inserted in them. Apparently the bear or bears had been frightened from the carcasses. Due to the hard grassy ground, no bear tracks were noted in the area so it was not learned for certain whether the bear making the attack was a grizzly or a black bear. However grizzly tracks were seen a mile from the kills, and the distance between the tooth marks on one side of the neck indicated that the bite was made by a grizzly rather than a black bear.

Case III. On July 19, near Sagebrush Flat on Spread Creek, the remains of a yearling which had been eaten by a

bear were examined. A grizzly had been seen near the carcass a short time before. The bones were scattered but the hide was largely intact. There were tooth holes in the hide at the base of the neck and in the lumbar region of the back. The size of the holes and their spacing were such that they undoubtedly had been made by a bear. The evidence here is perhaps not so conclusive as it would be if the fresh carcass had been examined, but in the light of the information gained later about the kills there is no doubt about the cause of this yearling's death. The carcass was in rather dense woods near the creek bottom.

Case IV. On August 3, while the author was in the field with Forest Supervisor Buckingham and Ranger Verland Taylor, four cattle carcasses were found. Three of them were considered bear kills.

In the afternoon, about a half mile above the mouth of Grizzly Creek on Spread Creek, ravens called attention to the fresh carcass of a female calf which we judged to be about three months old. The remains were in a swampy spot in the willows at the edge of a grove of lodgepole pines where cattle had been bedding down. Deep tooth wounds on both sides of the neck, high on one side and low on the other, indicated that a bear had killed the calf. The dorsal process of a vertebra had been severed at its base. There were also tooth marks on the shoulder. The paunch and intestines had been removed. The brisket and the meat off the adjacent ribs and proximal ends of the front legs were eaten, and a considerable amount of meat had been eaten off the hindquarters. The liver, heart, and lungs were gone. A pool of water nearby, over which the carcass had been dragged, was discolored by blood. The animal appeared to have been killed sometime during the morning. Two or three miles above the spot we had seen several cows traveling and it occurred to us that they may have been frightened by the bear. Beside the carcass in the soft mud was a clear impression of the front foot of an adult grizzly. The track measured six inches wide.

Case V. About a quarter-mile above the drift fence on Flagstaff Creek three ravens were seen to fly from a spot where a calf, about 6 weeks old, was found. There was a hole in the hide close to the skull and the neck was deeply bruised on the other side. This bruise appeared to have been made by a bear's paw. The meat was eaten off the brisket and proximal ends of all the legs, and the heart, lungs, and liver had been eaten. The intestines and stomach had been carefully removed. The mother was nearby and 30 or 40 cows were feeding in the area. This appeared to be a fresh bear kill because of the severely bruised neck and the neat removal of stomach and intestines. Furthermore, a grizzly had killed a yearling only a few hundred yards away.

Case VI. Beside the trail about a quarter-mile from Case V we came upon the carcass of a fat yearling which had been dead about two days. The flesh was eaten off the brisket, ribs, and proximal ends of all four legs. The stomach and intestines had been carefully removed. A deep bite in the neck had partially disarticulated the second and third cervical vertebrae. At the

kill there was a grizzly track which measured just short of 6 inches wide. The track was slightly smaller than the one seen at Grizzly Creek earlier in the day but the difference in measurement could have been due to the variation in impressions. In the lungs were a scattering of small nodules full of pus such as had been found in the yearling killed July 13. Whether or not these indicated poor health is not known, but the writer believes they were not significant. Cases V and VI were about three miles from Case IV.

Case VII. On August 4, on the Spread Creek trail about a mile and a half above Grizzly Creek, a fresh grizzly track (about 6 inches across front foot pad) was seen in the trail. A short distance farther on, marks in the grass and willows showed where something had been dragged. Following the drag marks through the growth of willows the remains of a calf (2 or 3 months old) were found, largely eaten. The neck was eaten but on the hide there was a tooth pattern indicating that a bear had bitten the calf in the neck near the skull. The flesh side of the skin was bloodshot. There was also a tooth pattern on the hide over the lumbar part of the back indicating a bite there. The entrails had been removed but had disappeared. A cow with a big bag, perhaps the mother, was seen a quarter of a mile away. It appeared that the calf had been killed on the trail which here passed through a dense stand of willows. The drag marks started on the trail. This kill was about a mile above a kill noted near Grizzly Creek on August 2.

Case VIII. On August 7, accompanied by O. J. Murie, the author rode down Flagstaff Creek, up the North Fork of Spread Creek, and back to Twogwotee Cow Camp by way of Bull Creek. On Flagstaff Creek a short distance from where a calf had been found killed on August 2, the carcass of another calf was found which appeared to have been dead four or five days. On August 2 the presence of a cow with a big bag in addition to the cow showing concern over the dead calf being examined had been noticed. It seemed that a second calf which was not found had been lost. The state of decay of the calf found on August 7 was similar to that of the calf which had been dead since August 2. There was not much remaining of the carcass but on the hide there was a tooth pattern indicating that a bear had bitten the calf on the dorsal part of the neck. In the light of the attending circumstances it seemed certain that this calf was killed by a bear.

Case IX. On August 7 the fresh carcass of a calf about two months old was found at the edge of the willows on the stream bottom, 100 yards from the drift fence at the mouth of Flagstaff Creek. Much of the flesh had been consumed. On the neck, dorsally, near the skull, there were two tooth wounds on one side and three on the other. The teeth had penetrated deeply into the flesh but had not crushed the vertebrae. There was also a bite on the shoulder and here the teeth on one side had grazed the hide a short distance before penetrating. A grazed line, 2 inches long, on the hide of the base of the neck, may have been made by a claw. The entrails had been removed. After examining the carcass we felt certain that a bear had killed the calf. This

PLATE 1. *A*. The remains of a yearling killed by a bear. The bear had fed on both sides of the brisket and between the hind legs. This carcass was still warm when discovered. *B*. The fingers show the location of five tooth holes which extended into a vertebra that was bitten through. *C*. The skin over the neck has been removed to show the location of the bloodshot area at the base of the neck where the bear bit the yearling. *D*. The paunch of this calf was removed by the bear. Removing the paunch of a kill seems to be regular procedure.

carcass was only a few hundred yards from three other bear kills on Flagstaff Creek.

Case X. On September 26 Ranger Verland Taylor found a calf killed on Spread Creek not far from Grizzly Creek, where a kill had been found on August 2. The liver, lungs, and heart were still in place. The stomach and intestines had been removed. There were deep tooth wounds in the lumbar region of the back but none on the neck. The animal had apparently just been killed for it was warm and only a few mouthfuls of flesh had been eaten. Taylor, who had helped examine cattle killed by bears, was certain that this was a bear kill and was of the opinion that he had frightened the bear from the carcass.

CATTLE LOSSES IN 1946

The official loss figure on the Spread Creek-Black Rock Creek ranges for 1946 was 24. Of these, 11 were attributed to bears. The writer examined 11 of the 24 carcasses. Two of these died from unknown causes, two from causes other than predation, and seven from bear predation. Three animals that had apparently been attacked by a bear and escaped were also examined.

CAUSE OF DEATH UNKNOWN

About a mile below Flagstaff Creek the carcasses of two yearlings had been eaten by bears but the cause of death could not be determined.

LOSSES NOT DUE TO PREDATION

A cow and a yearling died from causes other than bear predation. The yearling, a fat steer, collapsed while being driven by the cowboys. As soon as the animal fell one of the cowboys bled it above the tail. This seems to be a standard remedy on the range for cattle when poisoning is suspected but apparently there is no experimental proof that the sick animal is benefited. In a short time the steer died. Its stomach was full of a lush green sedge so it is possible that bloat was the cause of death. There was nothing to indicate the cause of the other animal's death, but it apparently was not a bear kill, because there were no tooth marks on the hide.

CATTLE-BEAR INCIDENTS IN 1946

In 1946 remains of a yearling and six calves that were thought to have been killed by bears were examined. Also, two calves and one yearling were seen that appeared to have been attacked by a bear and escaped, judging from the marks on the animals. The dead yearling had been killed by a large grizzly. It is fairly certain that the grizzly rather than the black bear is also involved in the other incidents because the tracks of three grizzlies, besides the one that killed the yearling, were constantly seen on the trails where the kills were found and no black bear tracks were noted in this area during the predation period. Two of the grizzlies, small males, were trapped at kills by the cowboys. In the fall a huge male grizzly was killed on Baldy Mountain, less than five miles from the spot where the large grizzly had killed a yearling. In addition to these three grizzlies, four others were reported to have been killed in the region. Early in the season a female grizzly is reported to have been killed by a cattleman on lower Spread Creek. In the spring of the year, in the Black Rock

Creek area, two or four grizzlies seen at a bait are reported to have been shot by hunters. A male grizzly was also shot in the fall over on Whetstone Creek about 10 miles from Black Rock Creek.

Case I. On July 5, along Black Rock Creek, the fresh carcass of a yearling was found. It was lying on its back on an open bar about ten yards from the water. Because the flesh at the base and inside of each leg had been eaten, the legs had fallen away and lay sprawled outward on the ground. The flesh had also been eaten off the ribs and brisket, and the vital organs were gone.

Marks on the head showed that a bear had killed the animal. The teeth of one jaw had penetrated deeply below an eye, and those of the other jaw had crushed through the base of the nasal bones and torn the rostrum wide open. The entire head was bloody. There were a few miscellaneous tooth or claw marks on the dorsal side of the neck and on the back, but these were not serious. The killing bite had been inflicted on the face. The carcass had been dragged five yards from the paunch, which had been removed at the spot where the animal fell. The ground was stained with considerable blood where the yearling had first been brought down. At the carcass and in its vicinity were large grizzly tracks, a front track measuring six and three-fourths inches in width.

During the night the same grizzly, judging from track measurements, had returned to the kill and eaten heavily, for only the hide and bones remained the next morning. The hide, with leg bones attached, had been dragged up a steep bank into the woods. In the evening when the kill was first examined eight or nine cows were grazing about one third of a mile away. They were gone in the morning except for a cow with a big bag that was wandering about bawling, looking for her calf. The bear may have killed the calf, for the bear's tracks were seen in the area where the cow was searching.

Case II. On July 7 a cow with a big bag was bawling at Lily Lake near Spread Creek. Four days later the dead calf was located not far from where the bawling cow has been seen. Only the hide and a few bones remained. The pattern of a bear's bite on the dorsal side of the neck, close to the skull, and the bloodshot hide around the bite holes, indicated that this was a bear kill. There were also tooth marks on the hide over the shoulder and lumbar regions. The calf was two or three months old. The writer could not determine the kind of bear that had done the killing but grizzly tracks were seen in the trail nearby.

Case III. On July 16 below Flagstaff Creek, a yearling heifer was noted that had been bitten in the face by a bear and escaped. There were tooth marks on both cheeks and on the upper part of the nasals. The tooth pattern conformed to the jaw spread of a bear. The teeth had not penetrated the nasal bones but had broken through the hide and slipped along the surface of the bone. The failure of the teeth to penetrate the bone was probably the reason for the heifer succeeding in making her escape. There were fly larvae in some of the wounds, and the entire face was greatly swollen. The heifer was thin and sluggish. There was a slight scratch on the shoulder that may have been made by a claw. This heifer was again

examined on July 26. The swelling on the face had gone down, but the animal was poor, and tired quickly when chased It was apparently recovering, but cattlemen say that recovery in such cases is extremely slow.

The cowboys reported that they had also seen a yearling steer that had escaped with bear scratches or bites on the shoulder, and a calf that had suffered a bite on the neck. The steer was quite sick when first seen but appeared to be much better a few days later.

Case IV. On the North Fork of Spread Creek a half mile or so above Flagstaff Creek the remnants of a calf, largely eaten, were found on July 15. There were tooth marks in the hide on the dorsal side of the neck, which indicated that this was a bear kill.

Case V. On July 15 a small calf, about a month old, carried bite wounds on the neck and the small of the back. The wound on the neck caused the calf to carry its head tipped to one side. The calf was so small that it was surprising it had escaped, but possibly the mother had interfered with the attack.

This wounded calf was suffering from diarrhea and was sluggish. It was not feeding normally for the mother's udder was greatly distended. The diarrhea may have been a result of the wounds, or possibly the calf had been sick at the time it was attacked.

A herder stated that one summer he had found some small calves wounded by bear and had concluded that the cubs of a female grizzly that was later killed had been attacking the calves.

Case VI. On July 26, accompanied by two cowboys and a state game warden, the writer examined a large calf that had recently been killed by a bear on Grizzly Creek. The teeth had penetrated the hide on both sides of the neck near the skull. The axis was chipped and loosened from the atlas. The flesh around the bite wounds was bruised and torn as though the calf had struggled in the death grip. There was a small bite in the lumbar region of the back but this wound was not serious. The liver, heart, and lungs were eaten, and the flesh had been eaten off the brisket and the ribs so as to almost disjoint the shoulders. The flesh on the inside of the hind legs was also eaten.

A trap set at this carcass was twice sprung by a bear before a grizzly was taken. Grizzly tracks were seen in the sand and trails at the mouth of Grizzly Creek less than a mile from the carcass.

Case VII. At the mouth of Grizzly Creek on July 26 a short distance from the above kill, the skin and head remains of a small calf were examined. There were tooth marks typical of bear on the neck close to the skull, and dried blood on part of the skull.

Case VIII. On July 26, about two miles above Grizzly Creek on the North Fork of Spread Creek, the skin remains of a calf showed the tooth pattern of a bear on the neck region and in the lumbar section of the back.

Case IX. Near the mouth of Flagstaff Creek a large calf had been killed on July 27. It had been severely bitten at the base of the neck. Fresh grizzly tracks were in the trail nearby.

Case X. On July 29, on Bull Creek, a calf about 4 months old which had apparently been wounded by a bear and escaped was examined. On either side of the backbone in the lumbar region were

tooth marks apparently made by a bear. There were four claw scratches on one shoulder, spaced as though made by one rake of the paw. The wounds contained considerable pus and fly larvae.

DISCUSSION AND SUMMARY

KIND OF BEAR KILLING CATTLE

It cannot be definitely stated that the predation observed was all done by grizzlies but the field circumstances strongly indicate the grizzlies rather than black bears were responsible for the losses. In 1945 only three of the kills were unquestionably made by grizzlies but the spacing of the tooth marks indicated that two others were also attributable to the grizzly. The tracks in the trails in the area where all the kills were made, and the short distances of these kills from known grizzly kills, made it highly probable that the grizzly was the predator in each case. Likewise in 1946 it seemed that the grizzlies were doing the killing. In one case grizzly tracks were at the fresh kill. And in the area where the other six kills were found and the three wounded animals were noted, grizzly tracks were regularly seen on the trails and no black bear tracks were observed in the area during the period when the predation took place.

NUMBER OF BEARS KILLING CATTLE

It is important to know if only certain bears take to killing cattle or if all bears kill when there is an opportunity. The sporadic occurrence of cattle predation by the black bear suggests that the habit is not general among the blacks. On the other hand the consistency of predation over a period of years on the grizzly range studied, suggests that grizzlies are more disposed to attack cattle. A number of grizzlies have been taken off the cattle range over a period of years but the predation has persisted. It could be that the grizzlies in the particular range studied have been acquiring the cattle killing habit by example and that always a few grizzlies with the habit have managed to carry on. It seems more likely that the grizzly, although mainly a vegetarian, is much more inclined to hunt cattle than is the black bear, and that on grizzly range some loss of cattle from the bears is generally to be expected. In 1946 at least two grizzlies were killing cattle.

INDICATIONS OF BEAR ATTACK

The most characteristic mark on cattle attacked by a bear was a bite on the dorsal side of the neck. In such cases two or more tooth marks made by the canines were present on either side and the teeth often penetrated into the vertebrae. Several cattle were also bitten in the lumbar region of the back which is a vital spot vulnerable to a bear's bite. Sometimes there were bites in both the neck and the lumbar region of a victim. Occasionally an animal was bitten in the head. A yearling was killed by a bite on the face, and another yearing was severely wounded by such an attack but escaped. The cowboys reported the death of a yearling that had been bitten in the face, and that another yearling had escaped with bite wounds on the face. O. J. Murie, on the Gros Ventre River a few years ago, in the fall of the year saw an animal that appeared to have a bear bite on the rostrum. A hole penetrated the nasal passage from above so that each time

the animal breathed the vapor could be seen issuing from the hole.

Occasionally an animal that had escaped a bear carried claw marks as evidence of the attack. A cattleman reported seeing a calf a few years ago with claw marks on both hindquarters. It appeared that the bear had grabbed him too far back to hold him. In 1946 on the high meadows of Pinnacle Butte O. J. Murie examined a yearling heifer that had escaped from a bear attack. There were two deep claw marks on the left side high up over the hip, and one hole on the right side. There were also several long scratches posterior of these, and one on the withers. Apparently the bear had tried to seize the animal but his claws had slipped, dug the holes, and the heifer had escaped before a bite could be managed. A rancher in the Dubois area reported a calf that had been similarly raked and had escaped. The claw marks on the shoulder of a calf that escaped even though it had also been bitten in the back have already been mentioned.

The author's observations indicate that the paunch and intestines of an animal that has been killed are immediately removed intact from the body cavity. On the other hand the viscera appear not to be removed from animals fed upon as carrion, at least not if the carrion is old when discovered by the bear.

Sometimes animals that die from disease or poison have an inflamed condition under the hide which resembles a bruise such as a bear might inflict. The inflammation is usually on the surface and only in local spots does it extend for any depth into the flesh. The inflammation on the neck of one of the dead calves was interpreted to be due to a blow from a bear because over the whole area the congestion extended deeply into the flesh and was localized. In a diseased condition the congestion is more widespread and on both sides of the body.

It seems almost too elementary to mention that the eating of a carcass by a bear is not proof that the bear killed the animal. Yet on such evidence bears are regularly accused of predation by bear trappers and cattlemen.

METHOD OF ATTACK

Traditionally, the grizzly's technic for killing cattle was supposed to be a crushing blow on the skull with a powerful forepaw. However, as has been discussed, death in every predation case examined except one, was definitely due to bite wounds.

In attacking, it appears that the bear seizes the victim with its arms, and then bites. The animal that has been seized and manages to pull away is the one most likely to be scratched. Those on which the bear manages to inflict a deep bite are probably less likely to be raked with the claws.

The actual attack has seldom been witnessed. Seton (Vol. II, p. 30. Lives of Game Animals) gives an incident in which a grizzly was holding a four-year-old steer with its fore feet and biting at its neck. In Alaska the writer once watched the attacking method of a grizzly which was fighting off five wolves that were protecting their den site. The wolves had surrounded the bear and were attacking from behind one at a time. To protect his rear the grizzly was making quick turns and lunging at the attackers. Each time he

lunged, both huge arms were stretched forward in a grasping position. There was no "swiping" at the wolves. Apparently the bear was endeavoring to catch them between his paws. If he had succeeded, his next move would no doubt have been to administer a bite.

There are not many observations on the hunting methods used by the grizzly. Some have said that the cattle, especially the yearlings, are curious, surround a bear, and come so close that the bear can rush out and seize an animal. Seton (Vol. II, p. 30) cites one such incident. A cattleman told me that from a distant ridge he had seen a group of cattle converge on a black bear in a thicket. When the cattle had approached within a few feet of the bear, it rushed out and killed one of them.

The writer has observed cattle showing great curiosity a number of times. While he was examining the first bear kill, a group of cattle crowded close to the carcass. It seems plausible that the curiosity of the cattle would frequently give the bear an opportunity to catch one of them.

One cattleman was supposed to have tracked a bear that followed a cow four or five miles before killing her. In one case which I observed, it appeared that a bear had come upon a calf on a trail through dense willow. Here the visibility was so limited that the bear could have come within a few yards of the calf before being discovered. At salt licks and in groves where cattle bed down during the day there might be opportunities for bears to make a close approach before being discovered.

AGE OF ANIMALS KILLED

Of the 17 kills recorded, 4 were yearlings and 13 were calves. Of the 3 animals that had been wounded but escaped, 1 was a yearling, and 2 were calves. Probably because of their smaller size, the yearlings and calves are taken rather than the adults. Some people state that yearlings fall prey to bears because cattle are especially curious at this age, and approach a bear so closely that they are easily captured. Older animals may be more bear-wise, and keep at a more discreet distance.

PHYSICAL CONDITION OF THE CATTLE KILLED

In some predator-prey relationships it appears that the catching ability of the predator is closely matched by the escape ability of the prey. Under such circumstances extensive predation may occur only when the prey species is at some disadvantage, such as weakness resulting from disease, or inadequate diet. With this in mind the remains of the cattle killed were examined for indications of abnormal conditions.

The victims of predation which were still largely intact all appeared to be in good flesh. The internal organs were missing in many cases, but where examinations could be made it appeared that the animals were in good health. The lungs of two yearlings had a few nodules with a pus-like substance in them but the infections were so slight that it did not seem that they were significant. It was especially interesting to learn the extent of the feeding on larkspur because bears are frequently accused of causing the death of animals

that have eaten this poisonous plant. An animal sick from larkspur, if he has not eaten too much, will recover if undisturbed, but might succumb if forced to exercise. Some cattlemen think that many poison losses are due directly to bears disturbing the sick animals. A reliable observer informed me that he had once seen a poisoned animal collapse after being disturbed by a bear. Although larkspur was common over most of the range, the stomach contents of the bear kills whenever available for examination contained very little larkspur, so that it seems unlikely that larkspur poisoning was an important factor in the predation. Apparently the bears were, on the whole, preying on healthy animals.

SEASON AND LOCATION OF BEAR PREDATION

Cattlemen reported that bear predation takes place during the entire period that cattle are on the forest. On the Spread Creek range most of the kills occurred when the cattle were in the Flagstaff and Grizzly Creek areas, which was in July and early August. As soon as the cattle passed on to the higher, more open ranges, the losses due to bears largely terminated. This appears to have been the situation for several years back. The explanation for this is not clear.

TIME OF DAY AND PREDATION

At least some of the cattle were killed during the daylight hours, two of them about noon. Since bears may be active at any hour, one would expect kills to occur at any time of day. Possibly cattle are most vulnerable when resting in the shade of a grove of trees, but there is no evidence one way or another on this point.

NATURAL FOOD SUPPLY AND PREDATION

It is possible that predation in some areas increases in years when natural foods, such as berries or acorns, are scarce. No information on this phase of the problem was secured. Berries are always rather scarce on the ranges studied, so the size of the berry crop probably was not significant in this case. There is the possiblity that the predation subsided in late summer because the bears moved to other areas where berries were more plentiful, but no evidence of such movements are had.

METHODS OF CONTROL

Bears are usually controlled either by trapping or hunting with dogs. From the standpoint of selectivity each method has its proponents, and some experienced control men feel that both methods are effective. No doubt the wrong bear may at times be taken by either method. In the use of dogs for running a bear down, it is stated that a pack may switch trails and end up by bringing to bay an innocent bear. And in trapping at a kill, there would always be the possibility of catching an innocent bear. Roughly it would seem that mistakes would be greatest where bears were most plentiful. Many feel that the use of dogs is more humane than trapping. Certainly if traps are used they should be attended daily. This would be no hardship for the

trapper for if he is trapping bears selectively there would be only a few traps to attend. Perhaps the most important requirement in obtaining selective control, whether dogs or traps are used, is a wholesome viewpoint in the personnel doing the controlling. The results of either of the above methods would probably be fairly satisfactory where there was a sincere, intelligent effort at selective control.

In the studies made it was found that the grizzlies returned to the kills even though they had been handled considerably. Three carcasses found on August 2, 1945, had all been revisited by the bear on August 4. If traps had been set at these kills at the time the carcasses were discovered the killer would no doubt have been taken. But a black bear, which was apparently innocent, might have been taken even the first night, for at the time it was feeding on the carcass of a diseased animal only a mile from a kill. The two kills on the Buffao Fork were not visited by bears the first four nights. The fifth night a bear fed on them. In view of the long interval since the kills had been made, there could be no assurance that it was the killer that returned. If trapping is the method used to control bears the greatest degree of selectivity would be gained by setting at fresh kills. There would be relatively little selectivity in setting at an old kill or at carcasses at random if bears were abundant.

CONCLUSIONS

The studies on Teton National Forest show a conflict between grizzlies and cattle on a common range, It is not known what proportions of the grizzlies take to killing cattle but it seems probable that a majority of them may becomes involved. If a large percentage of the grizzlies readily prey on cattle, then selective control, the kind of control which might be considered, would have little point from the standpoint of maintaining a grizzly population.

On the Teton cattle range the cattlemen have urged drastic control of all bears, some stating that a small black bear may be as harmful as a large grizzly, because they think that its mere presence might stampede cattle sick from poison and cause their deaths. On the other side we have the ranchers, sportsmen, wilderness campers, general recreation seekers, and wildlife conservationists, who wish to preserve a grizzly population in the region. Some in these groups have felt that if only a few bears are killing they should be selected for elimination. Others have stated that the cattle losses are relatively light and should be assumed by the stockmen for the privilege of using these lands which rank so high in recreation values.

Because the grizzly range in the United States is now so greatly restricted it is believed by many that the grizzly should be given special consideration in this region. A satisfactory solution will require land-use planning on a high plane, with all social needs carefully considered.

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A STUDY OF COYOTE RELATIONSHIPS ON CATTLE RANGE

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During the course of studies on rodent populations and their effect on range lands, attention was attracted to the coyote and its dual role as an important natural enemy of the native small mammal species, and as a menace to domestic livestock. The data here set forth were obtained from the 4,600 acres of the San Joaquin Experimental Range, California Forest and Range Experiment Station, U. S. Forest Service. The location was in the blue oak-Digger pine woodland foothill belt between 700 and 1,500 feet altitude. In this granite area of the foothills, the terrain is rugged, with many ravines and canyons, rock outcrops and boulder piles.

Collecting of scats was begun in September 1939. At that time, old scats were removed and discarded from several miles of roads and trails on the Experimental Range with the idea of making regular monthly collections of those subsequently deposited. Adherence to this program was prevented by changes and reductions in available personnel; the collections were irregular and often of uncertain date. All scats collected were found on roads or trails, which were known to be travel-ways of coyotes. Many of them were associated with tracks of coyotes, or were collected at the places, along ridges and their saddles, where they were accustomed to linger leaving droppings and scent. Other scats were tentatively identified as those of coyote on the basis of size and general appearance, and the fact that they were on regularly used travel-ways. Other carnivores inhabiting the area, were the gray fox (*Urocyon cinereoargenteus*), raccoon (*Procyon lotor*), bobcat (*Lynx rufus*) and badger (*Taxidea taxus*), and their scats may have been included occasionally.

In all, 1,173 scats tentatively identified as those of coyote were collected, with the following numbers in different months. In 1939: May, 1, August, 5, September, 23, October, 299, November, 237, December, 20; in 1940: January, 164, February, 26, March, 22, April, 3, May, 94, June, 32, July, 1, August, 3, September, 79, October, 26, November, 53, December, 1; in 1941: January, 20, and May, 64. In all there were 2,250 identifications of probable food items: 1,924 of vertebrate prey, 30 of large domestic mammals (as carrion in most or all instances), 254 of arthropods, 1 snail, and 42 of plant material. These items, classified according to several major groupings, are listed below in order of frequency of occurrence. MAMMALS: 414 ground squirrels (*Citellus beecheyi*); 377 cottontails (*Syl-*

[1] The writer is indebted to Kenneth A. Wagnon for field observations on coyote-cattle relationships at the time when coyotes were present in abundance on the area. The Madera County Agricultural Commissioner furnished data on numbers of coyote taken by state and Federal trappers. Scats were collected mainly by Frank Ahern, Oscar Hornback, Richard Loughery, Fenimore Ramley, and the writer, and were analyzed by Howard Twining, Daniel F. Tillotson, and John E. Chattin.

vilagus auduboni); 361 kangaroo rats (*Dipodomys heermanni*); 234 gophers (*Thomomys bottae*); 162 woodrats (*Neotoma fuscipes*); 62 pocket mice (*Perognathus inornatus* and perhaps *P. californicus*); 58 unspecified "rodents"; 17 mice of the genus *Peromyscus* (*P. boylii, P. maniculatus* and *P. truei*, probably all three represented); 17 meadow mice (*Microtus californicus*); 8 gray squirrels (*Sciurus griseus*); 5 harvest mice (*Reithrodontomys megalotis*); 3 chipmunks (*Eutamias merriami*); and 2 skunks (*Mephitis mephitis*). BIRDS: 33 unspecified; 7 quail (*Lophortyx californica*); 3 jays (*Aphelocoma coerulescens*); 3 chickens (*Gallus*); 2 towhees (*Pipilo* sp.); 1 canyon wren (*Catherpes punctulatus*); 1 mourning dove (*Zenaidura macroura*); 1 screech owl (*Otus asio*); 4 eggshells. REPTILES: 79 gopher snakes (*Pituophis catenifer*); 19 unspecified "snakes"; 17 rattlesnakes (*Crotalus viridis*); 9 skinks (*Eumeces gilberti*); 7 racers (*Coluber lateralis*); 7 "lizards" (unspecified); 3 alligator lizards (*Gerrhonotus multicarinatus*); 3 fence lizards (*Sceloporus occidentalis*); 2 king snakes (*Lampropeltis getulus*); 1 whip-tail lizard (*Cnemidophorus tessellatus*); 1 unspecified "reptile." AMPHIBIANS: 1 spadefoot toad (*Scaphiopus hammondii*). CARRION(?): 19 of cow, 4 of horse, 2 of hog, one each of sheep and burro, and 4 unspecified. ARTHROPODS: 116 Jerusalem crickets (*Stenopelmatus* sp.); 86 beetles (17 *Eleodes*, 11 *Coniontis*, 7 "carabids," 3 "tenebrionids," 2 each of *Phobetus*, *Pterostichus*, *Hydrous*, one each of "scarabeid," "hydrophilid," "dermestid," *Amara*, *Pleocoma*, *Prionus*, *Silpha*, 35 unspecified); 18 grasshoppers; 15 millipedes; 14 unspecified "insects"; 2 ants; 2 scorpions; 2 "arachnids." MOLLUSCS: 1 Snail. VEGETATION: 15 occurrences of grass; 10 of manzanita; 6 of acorn; 4 of coffeeberry; 2 each of strawberry and grape, one each of watermelon, apple, and ceanothus.

TABLE 1.—COMPOSITION OF COYOTE FOOD (VERTEBRATE PREY ONLY) BASED ON 1,173 SCATS

Prey		Occurrences in Coyote Food	
Species	Average weight in grams	Number of occurrences	Computed % by weight of total recorded prey
Cottontail	800	377	*45.4*
Ground squirrel	500	414	*31.2*
Gopher snake	500	79	*6.0*
Woodrat	200	162	*4.9*
Gopher	100	234	*3.5*
Kangaroo rat	60	361	*3.3*
"Bird" (unspecified)	215(?)	33	*1.1*
"Snake" (unspecified)	400(?)	19	*1.1*
Rattlesnake	300	17	*.8*
"Rodent" (unspecified)	100	58	*.8*
Other (24 kinds)	variable	170	*1.9*

Some of these items doubtless were taken accidentally; acorns in several occurrences were associated in scats with ground squirrel, and the squirrels often carry acorns in their cheek pouches. Also many of the insects, such

as ants, and silphid, or dermestid beetles probably were gulped down accidentally after having been attracted to the meat which a coyote was eating. Others of the smaller kinds were probably eaten by the birds, lizards, and toad which later became prey of the coyote.

It is evident that the plant, invertebrate, and carrion items combined made up a relatively small part of the food. Of the many vertebrate prey species, a few kinds which were both large and common made up most of the food bulk. The relative importance of the different prey species is best shown assuming one average sized adult of the species in question for each scat occurrence. Murie (1946) has shown that this would hold true approximately for animals of squirrel or rabbit size, though counted "occurrences" of mouse-sized animals might be considerably below the actual numbers represented:

The approximate order of importance in the coyotes' diet is brought out. Rodents and rabbits combined apparently make up about 90 per cent of the food in this locality. Snakes are calculated, on this basis, to comprise about 8 per cent of the diet, but the great differential in weight between young and adult snakes makes probable a much wider margin of error than is involved in the calculations for the mammal species. If most of the snakes eaten were young ones, their percentage in the diet would have been much smaller than that calculated.

Seasonal changes in food sources were relatively unimportant. For each of the five months represented by extensive samples of more than 100 prey items—September, October, November, January and May—the percentages of numerical totals are shown for different kinds.

TABLE 2.—PERCENTAGES OF MONTHLY TOTALS COMPRISED BY DIFFERENT KINDS OF VERTEBRATE PREY

	September	October	November	January	May
Total Vertebrate Prey Items	162	571	456	277	267
Cottontail	*13.0*	*20.1*	*20.6*	*23.5*	*19.3*
Ground squirrel	*29.7*	*23.2*	*19.5*	*10.8*	*27.4*
Gopher	*17.3*	*10.5*	*10.1*	*9.4*	*19.5*
Woodrat	*4.9*	*7.2*	*7.9*	*13.1*	*7.9*
Kangaroo rat	*15.4*	*17.3*	*21.2*	*23.1*	*12.4*
Other rodent	*6.7*	*10.4*	*6.1*	*11.9*	*6.0*
Bird	*.6*	*1.7*	*4.6*	*3.2*	*2.6*
Reptile	*12.3*	*9.7*	*7.9*	*4.2*	*6.3*

The same kinds of prey are eaten all through the year, and their proportions in the diet change only slightly according to season. The cottontail was least represented in September at the end of the dry season—its annual population low when there are no small young. The proportion of ground squirrel decreased through the fall and winter following a downward trend in the actual number of squirrels to their annual low point in late winter. Kangaroo rats and woodrats both are apparently taken more in

winter than in fall or spring.

The coyote population was high on the area in 1935, although some degree of control had been applied for many years in the county as a whole. After loss of four calves in the winter of 1935–36, control measures were instituted on the Experimental Range. State and Federal trappers took the following numbers of coyotes in different years: 1935–36, 35; 1936–37, no record; 1937–38, "about 30"; 1938–39, "about 30"; 1939–40, 13; 1940–41, 13; 1942, 7; 1943, 5; 1944, 8; 1945, 1. Each year also an unknown number was eliminated from adjoining ranches. It is evident that in recent years the population has been held far below its former level.

Coyotes were especially in evidence at the time of calving in late fall of 1935. The Experimental Range herd had been bred earlier than was customary in surrounding ranches. Kenneth A. Wagnon, in charge of animal husbandry studies at the Range, was of the opinion that coyotes concentrated on the area for this reason, as they are known to feed on the afterbirth of cattle. Also, rodent and rabbit populations were higher than on adjoining ranches where some control was usually applied. The coyotes present in late fall and winter may have included some which had moved down from higher altitudes. At first they were bold and indifferent to humans, and often several or many were seen in the course of a day.

During November and December 1935, Wagnon on numerous occasions recorded seeing coyotes in proximity to cattle. On November 6 he recorded "two large coyotes were worrying 2 cows and 7 calves." On November 8 a coyote was found eating a dead calf which, from the appearance of its wounds, apparently had been killed by coyotes. On November 9: "heard a calf bawl in fright, and when I rode into the gully where it was, a large coyote ran out the other side; calf was unharmed but frightened and breathing hard as if it had been chased." On November 11: "Calf has been attacked . . . has large gashes on the left flank, right hip, and a large one on the right foreleg which has crippled it." On November 15 this same calf had been attacked again, it had new gashes on its right flank, and had lost about two-fifths of its tail. On December 10 it was found nearly dead, with new wounds, its left ear bitten off, and only three inches of tail remaining. The following morning it was dead and partly eaten. On November 14 another isolated calf was found badly wounded in its right flank. The wound had become infested with maggots. The same day, at 5:00 P.M. a group of stock highly excited was found bunched against the fence of an adjoining pasture through which, evidently, a missing calf had just been chased.

A certain cow, "Number 33," of the Experimental herd, due to drop her calf, was last recorded on November 21, or doubtfully, on November 24. Evidently she died in calving. On December 6, Wagnon discovered the remains, —"coyotes had her almost completely eaten, and the bones were quite scattered. Probably dead 5 or 6 days." In an interval of from less than one to possibly 2 weeks, this 750 pound animal had been mostly eaten, attesting to the numbers and voracity of the coyotes present then.

Of the 4 calves which disappeared or

were found dead and partly eaten during a short time, all were almost certainly victims of coyotes. No stray dogs or other large predators were known in the vicinity. After the elimination of 35 coyotes within a few weeks, the depredations ceased, and did not recur in the subsequent 11 years, though each year there were some or many coyotes in the pastures at calving time. Of the original lot caught, one large old adult with worn teeth, was tentatively identified as the calf-killer by the trapper.

In the fall of 1941, an adult female coyote was trapped and kept for more than a month in a feeding experiment. For 34 consecutive days in which all food items offered were recorded and weighed, it consumed: 21 adult ground squirrels, 9 kangaroo rats, 2 gophers, 5 sparrows, and one each of jackrabbit, cottontail, white-footed mouse, jay and towhee; 2 pounds of grapes, and 1.34 pounds of Bologna—a daily average of 1.19 pounds of food. During the first week, perhaps because of injury and confinement, this coyote refused some food, but later it ate everything offered, not even leaving scraps, and giving the impression that it would have eaten considerably more if the additional food had been available. If the average daily food consumption under natural conditions amounts to 1.5 pounds, as seems probable, then the 40 plus coyotes on the Experimental Range in 1935 would have eaten 60 pounds daily or approximately 11 tons annually. This would have amounted to four and three-fourths pounds per acre for the 4,600 acre Range area if their feeding had been confined to it. According to the food composition calculated in Table 1 this weight would be distributed as follows: cottontail 2.16 pounds, ground squirrel 1.48 pounds, gopher snake .28 pounds, woodrat .23 pounds, kangaroo rat .16 pounds, other .34 pounds. Predation of any such intensity would seemingly place a severe strain on the reproductive capacity of those prey populations bearing the brunt of it. The cottontail with a breeding population calculated at .83 per acre in 1939 and .38 per acre in 1940, on a sampled 80 acre area, and the ground squirrel with a breeding population calculated at three to four per acre in 1939 to 1940, 1941, 1942 and 1946 on the same sample area, would have most or all of their annual increase eliminated.

An unknown factor, however, is the cruising radius of the coyote. Probably each one on the Experimental Range hunted over an area greater than the assumed seven square miles and, if so, the effect of their predation would have been less intensified. In this connection, the carrion occurrences in scats are suggestive; of the 30 recorded, eight (four of horse, two of hog, one each of sheep and burro) were of kinds not available on the Experimental Range, and must have been obtained from the surrounding ranches, while the remaining 22, mostly of cattle might have been eaten either within the area or outside of it.

The great reduction of coyotes on the area after 1935 had no conspicuous or evident effect on prey populations, but definite figures as to rodent and rabbit numbers were not obtained until 1939. Kangaroo rats, however, were at a population peak of possibly 30 or more per acre at about the time coyotes were subjected to control. Largely released from coyote predation pressure, the kangaroo rats nevertheless

underwent drastic reduction, to 4–7 per acre in 1939, 1940, 1941 and to only one per acre in 1946. The cottontail population underwent reduction from 1939 to 1940. Earlier figures are not available, but notes by Wagnon in the summer of 1936 indicate that they were conspicuously abundant then. The ground squirrel population did not increase noticeably at any time after coyote control was begun, and by 1946 had decreased on some areas.

In summation, the available evidence suggests that coyote predation is not a determining factor in the trends of ground squirrel, cottontail, kangaroo rat, and gopher populations in this type of habitat, despite the fact that these small mammals comprise the bulk of the food and are taken in great numbers. Relations with range cattle are generally harmonious, but individual coyotes, which learn to kill small calves, may cause serious damage at times.

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PRODUCTIVITY AND YIELD OF THE GEORGE RESERVE DEER HERD[1]

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This paper deals with the history of the George Reserve herd of white-tailed deer (*Odocoileus virginianus borealis* Miller) since its introduction in 1928 through November 1946, and especially with what has happened to it since the winter of 1933–34. By that time the herd had grown from six to 160 animals; controlled hunting was then begun to reduce the over-population and to protect the vegetation on the Reserve. In 13 years of harvesting the surplus, 546 deer have been taken and the population remaining in the winter of 1946–47, before removals, was 74. In round numbers, the average winter population before the take has been 127 (based upon 14 years' data), the average take has been 42 (based on 13 years' data), the average carry-over population 84, and the average fawn crop 37. In terms of percentages, the average harvest has been 33 per cent of the winter population and the average fawn crop added to the carry-over has increased the population 44 per cent. Both bucks and does have been removed. Eighteen deer have been found dead, about three per cent of all animals produced.

Although confined within a fenced enclosure, the herd is in no sense domesticated. It has not been artificially fed. The productivity of the herd is, in our opinion, governed by much the same conditions that would apply to a similar herd on a similar area of unfenced land.

[1] We are glad to acknowledge the help and general supervision of Professor Frederick M. Gaige, Director of the Museum of Zoology during the greater part of this study.

The Edwin S. George Reserve is a tract of land owned by the University of Michigan and administered by the Museum of Zoology as a natural area. It is about 1,200 acres of rough, morainic land situated in the southwest corner of Livingston County, about 25 miles northwest of Ann Arbor. The present cover types consist of approximately 26 per cent mixed hardwoods (mainly *Quercus-Carya*), 11 per cent tamarack (*Larix laricina*) swamp, 6 per cent brush, largely around the margins of swamps and bogs, 4 per cent bog, 7 per cent marsh, and 46 per cent grassland. The cover types are well interspersed. There is no white cedar (*Thuja occidentalis*) but junipers of two species (*Juniperus communis* var. *depressa* and *J. virginiana*) are plentiful and widely scattered in the more open woods and grasslands. Submarginal now, as far as agriculture is concerned, the land was once in private ownership; there are a few old fields, orchards, and fencerows that give evidence of its former use as farmland. The greater proportion of the land, however, was used for pastures and woodlots on most of the farms that occupied it, especially during their later years of operation. The Reserve was given to the University in 1930 by Colonel Edwin S. George, who had purchased and developed it as a country estate a few years earlier.

The deer herd is incidental. Colonel George fenced the area and stocked it, not as a hunting preserve, but because he wanted to see deer about his country home. In March 1928 he introduced four does and two bucks from Grand Island (near Munising, Michigan, in Lake Superior). No particular attention was given the herd in its early years, but in the fall of 1933 it became apparent that the deer had increased phenomenally and that vegetation was being drastically overused.

The first deer drive and count was made on December 3, 1933, under the direction of Mr. Paul Hickie. The total count was 160 animals, with no attempt to classify them as to sex and age. As Hickie (1937) has pointed out, the count was probably not completely accurate but it was close enough for practical purposes. It is the best beginning figure that we have for population studies on the area.

In January 1934 harvesting by shooting was begun; at different levels of intensity it has been continued to the present. Since the kill for 1946–47 is not yet complete, it is wholly omitted from this report. The two sexes have been taken almost equally, and a few fawns have been shot each year. Twelve live fawns (counted as part of the harvest) have been removed for experimental work. Eighteen deer have been found dead of gunshot wounds, accidents, and causes unknown. Most of the shooting has been done under the strict supervision of one man and losses from wounding have been exceptionally few. The known removals—harvest plus losses—have totalled 564 and have been in the ratio of 113.5 males to 100 females, or 53:47.

There have been no known losses due to disease or parasitism. Foxes may have killed a few very young fawns, but we have no record of it; indeed, although Murie (1936) studied fox food habits on the Reserve at the time of greatest deer abundance, he found no evidence of predation on fawns. The

fence is a six-foot span of heavy woven stock fencing with a five-wire barbed wire overhang, making it seven feet high altogether; it is not absolutely deer proof, but we think that the net loss, if any, has been small. We know that at least two deer have escaped, and at least two have come in, over the fence. There were a few deer in this region in 1928 and they have since become numerous: the increase is over too large an area, however, to be the result of escapes from the Reserve.

Since the first deer drive, other counts have been made in 1935 and 1936, and each year from 1939 through 1946, in the early winter. The counts were made by voluntary workers, mostly students and faculty of the School of Forestry and Conservation and the Museum of Zoology. The drives have been planned and directed largely by the senior author, with the help of Drs. William H. Burt, Museum of Zoology, and Samuel A. Graham, School of Forestry and Conservation. Methods of planning and executing the drives have varied from time to time. Sex and age tallies were generally attempted. Some of the results are believed to be good, others less reliable: counts made early in the season before the bucks had shed their antlers naturally gave better information than those which were made after the antlers had been lost, and some of the census crews were more skillful than others. The drives were more often training exercises than drives by experts.

To go into the details of the census methods is beyond the scope of this paper. Briefly, a line of drivers generally drove the deer through a line of counters; both lines tallied the deer according to a pre-determined system. As mistakes occurred, attempts were made to rectify them by improving the method the next year, always keeping in mind that the best deer drive is the one in which the animals are least disturbed and that, in a fenced area, precautions must be taken to prevent the deer from being driven into the fence where they may injure themselves. To get good results the men must be good observers who understand how the drive is being conducted, and who will follow directions and do team work. Long experience with deer drives on this area shows that massed manpower drives are unnecessarily expensive, and that better methods must be worked out.

Our most accurate records are those concerning the animals harvested. In 1934 records were kept by Dr. Adolph Murie. From 1934 to 1939, O'Roke kept autopsy records of those animals which were examined for lungworms; these data include weight and estimated age. Beginning in 1935 Mr. Lawrence Camburn, Custodian of the Reserve, who has been in charge of all hunting after the first three winters, kept a record of all animals harvested. We gratefully acknowledge Mr. Camburn's help, for without his records this study would be incomplete.

A final source of information comes from summer field observations from time to time on the fawn crops. These data have served as a check on the censuses, in some cases, and in others have given us a basis upon which to interpolate estimates of the population in the absence of a census.

By tabulating all of the data and interpolating to fill the gaps, it is pos-

sible to show the population characteristics of this herd over a period of 19 years (Table 1). The figures for the early winter populations are actual census figures, plus removals before the census, unless otherwise noted. Fawn crops were calculated by subtracting sus nor estimate of fawns, are thus determined by the estimates for the year before and the year after. In general, the deer drives did not give an accurate tally of the sex and age composition of the herd, and so we have not used those figures.

TABLE 1.—SUMMARY OF POPULATION STATISTICS, 1928–1946

Year (April through March)	A Spring Population (C–D of the year before)	B Calculated Fawn Crop (C–A)	C Early Winter Population*	D Removals (Shot, found dead, etc.) ♂♂	♀♀	?	All	E Calculated Annual Increase in % (B÷A)	Remarks
1928–29	6								
		154							
1933–34			160	6	3	1	10	±*60.0***	
1934–35	150	60	210	58	37	1	96	*40.0*	Fawn crop est. 60
1935–36	114	14	128	12	5	2	19	*12.3*	Fawn crop est. very low
1936–37	109	83	192	20	20	1	41	*76.1*	Fawn crop est. 80
1937–38	151	18	169	53	47		100	*11.9*	Fawn crop est. 18
1938–39	69	49	118	16	20		36	*71.0*	
1939–40	82	30	112	23	14		37	*36.6*	Fawn crop est. low
1940–41	75	44	119	18	28		46	*58.7*	
1941–42	73	27	100	26	23	2	51	*37.0*	
1942–43	49	51	100	21	20	2	43	*104.1*	
1943–44	57	32	89	15	18		33	*56.1*	
1944–45	56	25	81	15	15		30	*44.6*	
1945–46	51	26	77	12	10		22	*51.0*	
1946–47	55	19	74					*34.6*	Fawn crop est. 21
Totals		632		295	260	9	564		
Average: Production	83.9	36.8	120.7					*43.8*	1934–35 through 1946–47
Harvest			127.3				42.0		1933–34 through 1945–46
Losses (Deer found dead)							1.4		1933–34 through 1945–46

Figures in bold face are interpolations. See text for explanation.
* Census figure plus removals before the census.
** Rate of reproduction after herd had become large enough to rule out distortion due to small numbers. See text for fuller explanation.

the spring carry-over from the corrected census figure: note that it takes two consecutive censuses to calculate one fawn crop. When there were no census figures, fawn crops were interpolated on the basis of field estimates, except for the spring of 1938. All the interpolations, therefore, have some basis: a known carry-over plus an estimated fawn crop gives an estimated winter population, or a known winter population less an estimated fawn crop gives an estimated spring population for that year. Even the figures for the spring of 1938, with neither cen-

DISCUSSION

The data in Table 1 would, of course, be more valuable if none of them depended upon estimates or interpolations, and if the censuses themselves had been uniformly excellent. But since the record is cumulative, an error in one year—in census or interpolation—must be compensated for in another year. With no deer to start with, we know how many were stocked, how many have been harvested and found dead, and about how many are left. From this it is possible to calculate about how

many must have been produced to give the known removals. If there is any considerable error it probably means that more deer have been produced than our figures show, rather than fewer. More deer may have died than were found, especially among fawns. We know that deer have occasionally jumped the fence, sometimes in and sometimes out: with a high population inside the fence, it seems likely that more deer have escaped than have come in. We believe that errors from these two sources are small, however. Granted that the figures for any one year might not be wholly accurate, when grouped into periods of several years each the data should be useable.

PRODUCTIVITY

The reproductive potential of the white-tail is not definitely known, even now. Most authorities have agreed, in the past, that does generally bear their first young at two years, bear but once a year and average 1.5 or 2.0 young per year during their reproductive life. Morton and Cheatum (1946) more recently have found an average of 1.0 embryos in 36.2 per cent of doe *fawns* examined, and an average of 1.7 embryos in 92.3 per cent of older does, in southern New York; they found at the same time that the breeding rate in the Adirondack region of northern New York was considerably lower. Their work indicates that the earlier ideas on the breeding age of deer will have to be revised, and that there are considerable differences from one region to another.

The growth of the Reserve herd to 160 animals during its first six years can be used to explore the possibilities outlined above. The four original does were adults and presumably fawned during their first summer on the area (Hickie, 1937); that assumption is common to the comparisons below, which allow several alternatives for the reproductive potential of deer.

One set of alternatives assumes that, on the average, the first fawns are born when the does are two years old:

	First fawnings	*Later fawnings*	*In 6 years*	*Authority*
(1)	2.0	2.0	166	(Hickie 1937)
(2)	1.5	1.5	101	(Leopold 1933:32)
(3)	1.0	2.0	130	(Burt 1946: 257)

Although the first alternative seems to fit the recorded increase remarkably well, many fawns may actually breed in their first autumn. Kelker (1947) found circumstantial evidence that some fawns in the Reserve herd did so. Using Morton and Cheatum's figures for southern New York, since that area is more comparable to southern Michigan, assume that 36.2 per cent of year-old does, and 92.3 per cent of older does, bear:

(4) an average of 1.0 and 1.7 young, respectively, we have 129.3 in 6 years;
(5) or first year 1.0 and later years 2.0, we obtain 145.9 in 6 years.

(If the decimal fractions are converted to the nearest whole number for each age class each year, the totals are 140 and 152.)

Finally, it may be that the percentage of pregnancies in older does was higher on the Reserve than in southern New York, since none but the original four does would have had time enough to reach senescence during the six year period:

(6) same as (5) but *all* older does bear young—169.2 in 6 years (171 if fractional deer are converted to whole deer each year).

Without more data than we now have on the details of reproduction in the Reserve herd, we cannot determine which of the above possibilities—or of others still unexplored—comes closest to conditions on the area. Further, we do not know the extent to which *actual* productivity was reduced below *potential* productivity by environmental resistance. The figures above suggest that almost identical totals may result from quite different combinations of breeding age, numbers of young, and incidence of pregnancy, and that relatively small shifts in any one of the three components may make large differences in the rate of population increase. Deer irruptions might perhaps be the result of statistically small changes in the breeding rate.

The later history of the Reserve herd contrasts sharply with the first six years. Since all the original animals were adults the rate of increase was fastest in the first year. That early momentum had not been wholly lost even by the sixth year, but for practical purposes it may be said that the annual increase based on the total herd was then at the rate of about 60 per cent. Table I shows both that that rate of increase has not been maintained, and that reproductive success has varied widely from year to year.

Over the 13 years from 1934–35 through 1946–47 an average spring population of 83.9 deer produced an average of 36.8 fawns per year, an annual increase of only 43.8 per cent. During the period 1934–35 through 1939–40, when the over-wintering herd was largest, spring populations averaging 112.5 produced an average of 42.3 young per year, a still lower average annual increase of 37.6 per cent. During the last seven years, when the average spring population was 59.4 deer, the fawn crop averaged 32.0, an average annual increase of 53.8 per cent.

The annual increase has varied widely over the 13-year period. We do not know the precise extent of these variations, since the accuracy of the figures for any single year is often doubtful—the recorded increase in 1942–43 is almost certainly the result of census errors in that year or the year before—but summer field studies have shown without question that marked variations did occur. During the summer of 1934 Murie[2] estimated the fawn crop at 60. O'Roke[2] estimated it as "very low" in 1935, about 80 in 1936, "very low," with 18 accounted for, in 1937, and "low" in 1939. Carroll Smithson,[2] studying herd composition on the Reserve in the summer of 1946, estimated the fawn crop at 21. Two of these estimates can be compared with calculated increase based on census and removals: 1936, 80 and 83; 1946, 21 and 19. The year-to-year variations, then, can be accepted as valid, and seem to be on the order of 12–15 per cent for the lowest extremes and 60–70 per cent for the highest.

The poorest fawn crops did not follow unusually severe winters. The data for the summers following the two hardest winters in many years—1935–36 and 1942–43—are obviously out of line to some extent, but it is plain that productivity was not greatly lowered. The fawn : doe ratio in the "Conservation Officers' Deer Tally" (Mich. Cons. Dept. 1932–1945) does not indicate

[2] Unpublished field notes.

that the poorest years on the Reserve were unusually poor in the Lower Peninsula of Michigan generally. Smithson's notes show that as many as six or eight adult does may not have dropped fawns in 1946. An increased proportion of does beyond breeding age would help to explain why productivity is now lower than it was originally. But in the poorest years many does must have failed to produce fawns, while those same does must have borne fawns again in later years, else the over-all productivity could hardly have been maintained. We hope to get more data on this point from a study of breeding physiology which is now in progress.

It may be significant that the lowest extremes occurred during the period of greatest over-abundance (1934–35 through 1939–40). There are no directly comparable figures for the first six years after stocking, but it is inconceivable that the herd could have reached 160 (or anything close to it) if there had been even one really poor year. The fluctuations during the last seven years (1941–42 through 1946–47), like the average production for that period, seem to have been intermediate in degree.

The history of the herd may thus be divided into three periods of differing productivity. During the first six years, when the herd was "young" and building up from a small nucleus, its rate of reproduction averaged the highest (about 60%) and varied least from the maximum possible. In the next six years, a period of considerable over-abundance, the average productivity was lowest (37.6%), variations were greatest (12–15% to 60–70%), and the lowest extremes in productivity were reached. In the last seven years, during which the over-population was reduced but not eliminated, the average productivity and the variations from it were intermediate (53.8%, and 35% to ?%), and the poorest years were considerably more productive than the poorest years of the second period. No deer were shot until six fawn crops had been produced; from eight to 100 (average 42.0) have been harvested each winter since then.

Errington (1945) has described, for a number of other vertebrates, what appear to be comparable cases of productivity in inverse ratio to population density; concerning such animals as deer he has noted, less specificially, "a certain degree of self-regulation of numbers" (1946:157).

Our findings suggest that the George Reserve herd, in the absence of natural predation and with inadequate hunting pressure—in both of which it is comparable to many wild herds—tended to become to some extent self-limiting after it developed an overpopulation. We know nothing of the basic causes of this change in productivity, nor whether it could have kept the herd from destroying its range had it not been interfered with. The herd had already damaged the vegetation, but its own productivity was markedly depressed. Is there here a population mechanism which may forestall the final rise to an irruptive peak, and is the significant thing about deer irruptions not that they sometimes happen but that they happen so seldom? Does such a mechanism plus predation, rather than predation alone, hold wilderness deer in check? Is reproductive capacity violently upset by nutritional deficiencies

shortly before wholesale deaths by starvation begin? Does the lesser degree of variation in rate of reproduction at the lower level of popultion indicate that psychological, rather than nutritional, causes are involved? Darling (1946:35), indeed, speaks of "anti-social behaviour" as one of the checks on over-populations of the red deer (*Cervus elaphus* L.) in the Scottish highlands.

We do not know how closely the productivity of this herd parallels that of wild herds. In a general way, however, it does seem to have fallen within reasonable limits. During the first six years the Reserve herd exceeded most of the values suggested for the reproductive potential; during the later years, with a more nearly normal age composition, it came very close to some of them. It would seem, then, that these questions are worth following out. We cannot look for the answers in this herd because the other values of the Reserve may not be sacrificed to a deer study. We hope that someone will be able to do it elsewhere.

HARVEST

The general policy has been to take the two sexes about equally, and to shoot a few fawns each year. To that extent the kill has been selective, but there has been no attempt to regulate herd composition for maximum productivity. The main idea has been to remove part of the surplus, at first without fixed plan, then to keep the herd at about 75, and more recently at between 50 and 60. During most of the years more deer have been cropped than were produced, since the general trend has been toward a smaller carry-over. For that reason the 13-year average take of 33.0 per cent would seem to be higher than a sustained-yield management plan could support. During the first six years of cropping, with an average spring population of 112.5 and an average fawn crop of 42.3 (37.6 per cent), the herd would have been steadily cut down for a time by a one-third kill; however, it needed to be reduced. During the last six years, with an average spring population of 59.4 and an average fawn crop of 32.0 (53.8 per cent), slightly more than a third of the winter population was available for harvest on a sustained-yield basis.

We have had no experience, as yet, in cropping a small herd. So far, however, a rule of thumb harvest of one third of the winter population, taking both sexes, would seem to be good management of a well established herd.

DAMAGE TO THE RANGE

Deer damage depends upon the point of view. From the standpoint of deer production, the Reserve in its present condition could support its present 25–30 deer per section for many years; it could almost certainly support an even larger herd if there had not been so large an over-population in the early thirties. From the standpoint of the forester, the herd is probably still too large but not far from a reasonable size. There has been a noticeable improvement in the under-story since the herd was cut back to an average of about 55 in the winter of 1941–42, but oak reproduction is still being damaged severely and seedlings of maple and hickory are destroyed almost as soon as they appear. Pine plantations would have little chance for survival. Farming

would be possible only at large cost for deer-proof fencing or other kinds of crop protection.

The deer herd practically dominates the ecology of the Reserve. The area was critically over-browsed for a time, and the damage has by no means been undone as yet. True, there has been some recovery during the last four or five years, and with it there has been an increase in gray squirrels, chipmunks and cottontails, but the invasion of brush and trees into the old fields is still almost at a standstill. Red-osier dogwood, a preferred deer food, is much less abundant on the Reserve than outside, while the reverse seems to be true of witch hazel, which is browsed rather little. Orchids, trilliums, and lilies have been very scarce on the Reserve, but seem to be beginning to increase. These, however, are rough observations; a detailed study of deer pressure is now in prospect.

CONCLUSIONS

Although this study is not the result of the planned management of a deer herd, if any lessons in management are to be drawn from the performance of this herd, it would appear that the following are outstanding: Breeding deer cannot be held in an enclosure without provision for removing the surplus; if the annual surplus is removed promptly, other losses can be kept very low. After the herd has built up to a satisfactory stocking, 1,200 acres of land similar to this should be able to produce an annual bag of 40 deer, or one deer per 30 acres. It might be better, in the language of the forester, to make a 25 per cent allowance and assume one deer per forty. The harvest could probably be even larger if the herd were managed so as to keep its sex and age composition at the optimum for productivity; that optimum, however, is a function of the reproductive potential, which is still imperfectly known. Deer management also needs simpler census methods than the standard deer drive.

In our opinion, the most important contribution of this study to practical management is that a deer herd, under comparable range conditions, should yield a harvest of about one third of the winter population, year after year, if both sexes are removed in approximately equal numbers.

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NUTRIAS GROW IN UNITED STATES[1]

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The occurrence of nutria (*Myocastor coypus*), sometimes known as swamp beaver, South American beaver and coypu, in the catches of Louisiana trappers in recent years has been a source of great interest to managers of fur and game animals, fur tradesmen, and conservationists generally. The new source of fur has particularly encouraged those who are concerned with increasing fur production in the United States.

It is paradoxical that this new fur animal development was brought about by defeated and discouraged nutria breeders who released or permitted escape of these fur animals from captivity into the wild.

Raising nutrias has been of extensive interest and of speculation since ruthless hunting and uncontrolled trapping brought this animal to the verge of extinction in South America. Its history is a repetition of the chinchilla (*Chinchilla laniger*) and many other species of animals having an attractive fur that found favor with fashion and advanced in value as demand increased.

In 1849 nutrias were so abundant in all the rivers, estuaries, lagoons, and marsh lands of Argentina that Governor Rosas in his address before the Twenty-seventh Legislature of the Province of Buenos Aires referred to them as " . . . constituting great wealth destined to reward the troops after the war . . . ."

The nutria did reward the troops and many others so well for the following sixty years that those who lived by hunting and trapping this fur animal had virtually exterminated it and were forced into other pursuits for a livelihood.

Since then, protective laws were enacted, but this legislation was only partly effective in saving some of the nutrias that found refuge in isolated districts. The annual take of pelts decreased to where the demand was one hundred times that of the supply. So, when nutria pelt exports declined to an annual average of 175,600 for the five-year period 1924–28, breeding nutrias in captivity began.

Prices paid for nutria pelts took a

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sharp upward trend in 1922, but for some years before that the demand was far greater than the supply and the rise in prices caused the animals to dwindle in number. Skins reached $70.00 a dozen in 1923 and soared to $140.00 a dozen in 1924. By 1929 the price quoted on the Canadian raw fur market for extra large skins was $13.50 each.

As early as 1882, a few nutrias were raised in France and later (1890–92) the production of these animals became a private enterprise of amateurs. Nutria raising practically disappeared after the beginning of World War I, and it was not until 1925 and especially after 1927–28 that these fur animals were again raised extensively in captivity. Great hopes for financial success were unhappily ended as a result of the world economic crisis during the 1930's. Released or escaped nutrias occurred in several regions of France and in 1939 they benefited in the wild state by protection applying to other game (Bourdelle 1939).

Raising nutria in captivity in South America started in 1922. Nutria farms became numerous throughout the country and animals captured in the wild for breeding stock brought high prices. A hundred dollars a pair was not an unusual price. Early operations were small followed by a "boom," and as usual with a promise of large fortunes.

Germany, Switzerland, and France entered the industry importing nutrias from Argentina, and later the United States and Canada, followed by Russia and the Scandinavian and other European countries. All had a measure of success in raising breeding stock and selling the animals to others who desired to engage in the same enterprise. By 1928 Germany had a nutria population of about 3,000 on some 200 farms. The "boom" in Europe stimulated breeders in the United States and Canada but it did not last long and not many nutria farms were established, despite its big play in United States fur-farming periodicals and press. The first nutrias known to be born in North America were those on the La Forrest Fur Farm, Quebec, Canada 1931.

NUTRIAS IN CAPTIVITY

In South America, the first nutria farms were large fenced enclosures which included as much natural habitat as possible. Later on larger and more pretentious areas were fenced and partitioned into smaller areas for breeding and whelping, retaining pens, and feeding ranges where corn, clover, and alfalfa were planted. When the crops were ready the nutrias were turned in to do their own harvesting. The next development was to house the nutrias in small pens where they were under control similar to silver foxes.

When the first shipments of pelts from nutrias raised in captivity arrived in the raw fur markets, nutria farming began to decline. The size and quality of these skins were so inferior to those taken in the wild and the prices received for the fur were so disappointing that many breeders abandoned the venture immediately and others followed gradually. So ardent and persistent had been the pursuit of the animal for the monetary value of its fur that little or no time was devoted to a study of its life history or habits. Breeders soon began to realize that much serious study and experimental work was neces-

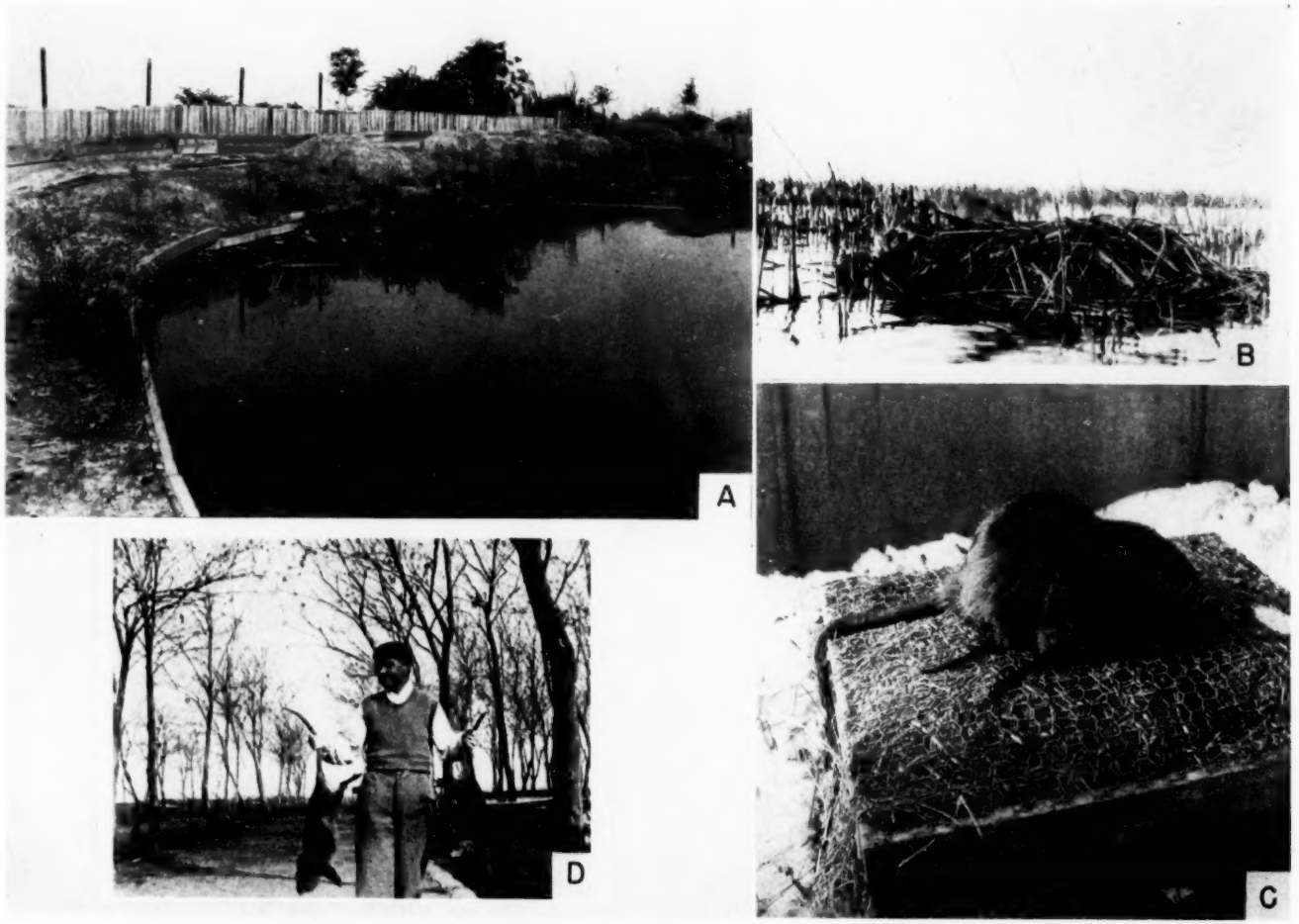

PLATE 2.—*A.* Nutria shelters of marsh hay located on the canal bank, McIlhenny nutria farm, Louisiana. (Courtesy Fish and Wildlife Service, photograph by Herbert L. Dozier.) *B.* A floating nutria house or nest built on a lagoon in South America. (Courtesy Fish and Wildlife Service.) *C.* Young nutrias nursing in pen. U. S. Fur Animal Field Station, Cambridge, Maryland. (Courtesy Fish and Wildlife Service, photograph by Herbert L. Dozier.) *D.* Proper method of holding and carrying nutrias. (Courtesy of U. S. Department of State.)

sary before a profitable business could be developed. Very few had the courage to undertake the task.

Some nutria farms continued but they were conducted mainly as centers of redistribution and the principal business of these so-called nutria farms was to hold animals taken in the wild for exportation as breeding stock.

Experimental nutria farming in Argentina extended over a period of 15 years and proved a costly undertaking to those who set out to raise nutria in captivity. They learned reluctantly that more money was spent in equipment, feed, and labor than could be realized from the sale of the fur.

By 1940, practically all the nutria farms in South America, Europe, and the United States had discontinued business, but a few continued on a shoestring basis. Some of the breeders in the United States became so disgusted that they turned the nutrias loose or allowed them to escape into the wild so as to preclude feeding and caring for them.

IMPORTS, RELEASES AND ESCAPES

The earliest record of nutrias imported to the United States was in 1899. Will Frakes brought from South America, one mature male and three young female nutrias to Elizabeth Lake, California. The late David Starr Jordan and C. Hart Merriam encouraged this venture. Frakes kept them in small pens for two years but no young were produced and there is no datum available reporting his experiences with these fur animals. As a matter of record Frakes did send a specimen to the National Museum, Washington, D. C. in 1900.

A nutria farm was established in the Green River area of Washington about 1932. An unprecedented flood swept this area in 1935 and floating logs punctured the woven wire fences enclosing the nutrias and they escaped into the wild. A pair of nutrias from the Green River farm was given to another enthusiast who desired to raise these fur animals in this same period but, having no success, liberated them. Still another nutria farmer, located on the south end of Lake Washington near the town of Renton, had seven nutrias in captivity and tried for seven years to raise them. After Pearl Harbor he was drafted but before he joined the armed forces he tried to sell them. He failed and in desperation turned them out into the marsh areas adjoining his farm.

From these escapes and releases the nutria became established not only in the Lake Washington region but in areas drained by the Snohomish and Skykomish rivers and their tributaries. It has travelled up the Cascade range to the headwaters of the Snoqualmie River about 60 miles from the town of Renton. Some woodsmen have reported seeing nutrias on the east slope of the Snoqualmie Pass. If this is true, they may migrate to the headwaters of the Yakima River where they could do damage to storage reservoirs and to irrigation projects in the lower valley.

Larrison (1943) reports colonies of nutrias near Garrison Lake, Nestucca River and Portland, Oregon; also near Sammamish River in the vicinity of Seattle and the La Conner and Fine Lakes areas in Washington. The earliest trapping record for nutria in Oregon appears to be 1938 and in Washington 1941.

Wildlife Service, photograph by Herbert L. Dozier.) *B.* A floating nutria house or nest built on a lagoon in South America. (Courtesy Fish and Wildlife Service.) *C.* Young nutrias nursing in pen. U. S. Fur Animal Field Station, Cambridge, Maryland. (Courtesy Fish and Wildlife Service, photograph by Herbert L. Dozier.) *D.* Proper method of holding and carrying nutrias. (Courtesy of U. S.

In 1937 E. A. McIlhenny established a nutria farm on Avery Island, Iberia Parish, Louisiana. The animals were kept in an area fenced by driving boards side by side into the marsh. About 1939 some of the animals escaped and during the same year 50 or more pairs were released. They took refuge in the marsh areas surrounding the island. Lowery states that McIlhenny reported (Lowery, 1943, p. 248) that trappers took nutrias in Iberia Parish, and that he heard of others being captured at Morgan City, Marsh Islands, Chenier au Tigre, Pecan Island, Lake Arthur, and in the marsh along the Sabine River near Toomy. Atwood (unpublished) reports that during September 1940 he found the first nutria in the Lake Arthur area, sixty-five miles by water, from Avery Island. These took refuge in the marsh areas surrounding the island. In Louisiana where the waterways are a network of rivers, lakes, bayous, and marshes, traversed in part by an intercoastal canal, the nutria had no difficulty in extending its range.

Nutrias were first trapped on the Sabine National Wildlife Refuge during the season 1941–42 and on Laccasine in the winter of 1943; both Federal refuges are located in Cameron Parish.

At the close of the 1945–46 trapping season Atwood (unpublished) states that nutrias extended their range westward as far as Whites Ranch, 15 miles west of Port Arthur, Texas and eastward as far as the west bank of the lower Mississippi River. By 1947 this exotic travelled east and south as far as the Delta at the mouth of the Mississippi River, for during January 1947 colonies of nutrias were found on the Delta National Wildlife Refuge. They migrated west to the Texas border and across the state line into the marsh areas along the Gulf of Mexico.

Nutrias in Louisiana are now established in the parishes of Iberia, Vermillion, Cameron, St. Marys, and Plaquemines. They have reproduced to such an extent since their release in 1940, that the state collected a severance tax on 8,784 such pelts during the trapping season 1945–1946, and 18,015 in 1946–47. The marsh åreas of Louisiana are capable of supporting large numbers of muskrats and nutrias which will undoubtedly increase the fur production in that state.

In 1939 nutrias were discovered on the Bitter Lakes National Wildlife Refuge, New Mexico. Prior to the acquisition of this land by the Federal Government, a nutria farm was established in the region near the Pecos River. Later a flood swept the nutrias down the river and those that survived established colonies an the refuge. The existing habitat is patchy, limited, and the food and cover is not the type particularly attractive to nutrias. Therefore, this fur animal has not reproduced in any appreciable numbers during the past eight years. It is estimated, however, that approximately 150 of them are now living on the refuge. Petrides (1946) reports the first nutria taken in Ohio was killed in a barn located at Whitehouse, Lucas County. It was eating corn with the pigs. Dr. William H. Burt of the University of Michigan has received several sight records of nutrias in Michigan. Harlan (1943) reports two young muskrat trappers in Iowa cap-

tured a strange animal later identified as a nutria. Presumably this animal escaped from a fur farm.

Releases and escapes of nutrias were undoubtedly made in other states for there are unconfirmed reports that indicate this to be the case. At first, trappers did not know what they were. They said they looked like a cross between a muskrat and a beaver but grunted like a hog. After much speculation and investigation all these appeared to be nutrias. How many were released and later trapped, is not known. Nor are there any data available on the number now at large. It seems reasonably certain, however, that this exotic fur animal is pretty well established in the States of Washington, Louisiana and Texas for they are being trapped and the furs sold in commercial quantities in these States.

Scattered records of nutria taken in Western Canada have been recorded but these are difficult to verify. These animals undoubtedly escaped or were released from fur farms.

DESCRIPTION AND CHARACTERISTICS

Because the early Spaniards believed this fur animal to be a form of European otter, they gave it the name "nutria." The word nutria is Spanish for otter. In more recent years the animal has come to be known as the South American beaver. Both terms, however, are misnomers.

According to Osgood (1943), the coypu has five recognized geographical races which together have an extensive natural range in southern South America. The species occurs in coastal areas and in larger rivers from approximately 15° South latitude in southern Brazil, Paraguay, and Bolivia to the Pacific coast of Tierra del Fuego. The coypu subspecies in Louisiana and Texas is probably *M. c. bonariensis*, the form from North Argentina, Uruguay, Paraguay, and South Brazil (Lowery, *op. cit.*).

On first sight a nutria on land looks like a stunted beaver with a long round tail, clumsy and possessing an unsightly fur covering. The head is typical of a rodent and resembles a guinea pig or an agouti.

It possesses four powerful incisors, orange in color and deeply set. The color of the incisors become deeper red orange with age, giving the animal an odd characteristic appearance. It has powerful cheek muscles like the beaver. The nutria can inflict serious wounds with these teeth and can cut off a handler's thumb or finger in one snap of the powerful jaws. The only safe way to lift a specimen is by the tail, holding it a safe distance from the body.

The short round ears and the long whiskers around the mouth make the head look broad, heavy, and coarse. The neck is short and the body broad with heavy covering of fur. The front legs are small, short, and have strong claws. The hind legs are longer, well muscled and the feet are webbed for swimming. The nutria's legs are scarcely long enough to keep the proportionately large body off the ground, giving it a clumsy appearance when in motion. When disturbed or excited it moves rapidly in short hops. The tail is black, long, perfectly round and thinly covered with flat lying bristles. The tail serves as a rudder when the nutria is swimming.

A full-grown male weighs from 20 to 25 pounds and a female from 15 to 20 pounds. The body is about 24 inches long and the tail 12 to 16 inches. The male can generally be distinguished from the female because he is larger and stronger in body and the head and neck are coarser than those of the female. In the female the mammary glands are well developed but they are located along the side of the back. The first of these is located at the height of the elbow of the fore-leg where the back begins to flatten down to the sides. On the height of the hip bone the last mammary gland is located. It seems to be generally accepted that this arrangement gives the young an opportunity to suckle while the mother is in the water. The irregular position of the mammary glands in the Rodentia is, however, not unusual. The guinea-pig and some species of *Capromys* have mammary glands on the inside of the hind legs. The porcupine has them above the arm pits and other rodents have them located similar to the nutria.

The common color of the nutria is dark amber in appearance but this varies with the type, season, and locality. The guard hairs are finer and not so long on the belly and sides as on the back and the under fur is also finer and denser.

The areas in South America inhabited by nutrias lie within a mild temperate zone where the winters last only three to four months, although hard freezes are not uncommon. The climate in these areas is similar to that in the United States but it is a marine climate and less fluctuating.

In the southern parts of Argentina and Chile the winters are quite severe. Streams freeze early in the season and remain frozen for a considerable period. The nutria is still fairly common in the Territories of Neuquen, Chubut, Rio Negro, and Santa Cruz, all within the extreme cold winter section of Argentine Patagonia and it is from these territories that the best nutria fur is produced for export trade to the foreign fur markets of the world.

The nutria takes readily to icy water throughout the Patagonian winters and apparently experiences no ill effect other than losing part of its tail. This is not common in all parts of South America and, since the animals so affected recover rapidly, the loss is considered inconsequential.

Nutrias in South America have been observed running over the ice of frozen rivers and lakes in search of a water opening into which to plunge and swim about. The young nutria a few days old is said to follow the mother into the same icy waters.

When nutrias were kept in captivity out of doors in Canada and in the Northern United States, the tails and feet of these fur animals froze and the condition was serious and a handicap to production.

FEEDING HABITS

The nutria is strictly herbivorous and feeds on a wide variety of succulent green plants, rushes, seeds, sour grasses, and aquatic plant roots. It is not too particular in selecting a menu. In captivity it shows a marked preference for alfalfa and clover and is fond of practically all root crops except white or Irish potatoes. In the marsh areas of Louisiana where the nutria is established it feeds extensively on the coarser vegetation, which it seems to prefer. Further study of the feeding habits of this

exotic in the United States is required to determine the various species of aquatic vegetation that compose the diet of this fur animal. Even in waters well stocked with fish, the nutria has never been observed eating them. Neither has this fur animal shown a tendency to molest the nests or eat the eggs of birds or waterfowl nesting in the same area.

The natural habitat of the nutria is along banks of fresh water streams, ponds and lakes; also marsh areas having an abundance of aquatic plants. They may burrow into banks close to the water level. Each pair makes its own burrow. They work in and up until well above the water level, clear a space and deposit grasses. As the family grows the burrow is enlarged since the offspring from one pair continues to live in the same burrow. If such a site is left undisturbed, in time it becomes the home of a large colony. As long as the water supply is sufficient and the feed plentiful the colony of nutrias will remain in the same locality for a long time.

A colony of nutrias may select a site in a marsh that has an abundance of weeds and rushes but which lacks banks. Here floating nests will be constructed of aquatic plants much after the same manner as the muskrats employ. Where natural conditions are favorable, part of the colony may make burrows in the ground and the other part will live in nests built in the marsh.

BREEDING AND REPRODUCTION

The breeding habits of the nutria are not so well known as those of the muskrat and some other rodents. The age at which a female will accept the male seems to be about 8 months but very few females become pregnant at this age. The heat period lasts from 2 to 4 days. Females bred at the age of 12 or 16 months are more likely to produce young successfully. The gestation period is 130 to 150 days. At the U. S. Fur Animal Field Station, Cambridge, Maryland, the gestation period was found to be 130 to 135 days. In the case of young females that give birth to young for the first time the period of gestation seems to be less (100 to 125 days) than for those that are suckling a litter and developing another at the same time. The young seem to be born through all the seasons and it is estimated that two or three litters are possible during the year. The number of young in a litter varies from two to eight. Young females seem to produce smaller litters than older ones. The general average seems to be about 5. The young are born with a good coat of fur and at birth are in an advanced state of development. In a few hours they are able to get about and after a few days they move around quite rapidly. They will leave the nest for short periods and scurry about with the mother. The young also begin to eat small quantities of solid food the first and second week after birth. The young are weaned at the age of seven or eight weeks.

TRAPPING AND PREPARING PELTS

Nutrias are trapped similarly to muskrats and the same types of steel traps are used. A trap set for a nutria must, however, be staked out more securely than one for a muskrat because the nutria being much stronger will pull the stake and drag off the trap. Traps commonly used to catch muskrats are not entirely satisfactory for trapping nutrias. Larger traps designed for other

fur animals such as number 1½, 2, or 3, are not suitable because the jaws and spread are too large, spring tension is too strong and the weight required to spring these traps is too great; therefore they are not adaptable for catching and holding nutrias. A new type of trap is required and experiments are in progress to develop a satisfactory trap for nutrias.

In Louisiana and Washington where nutrias occur in the wild, the trapping season is the same as that for muskrats. The best season for taking nutrias in the United States has not yet been established. It may be late winter and early spring. In South America, however, the mid-winter season is July through August.

The pelt of the nutria is taken "cased" and dried fur side in, similar to the otter and muskrat. A slit is made along the hind legs to the anus just as in the muskrat and the skins are pulled off in the same manner. The pelt is then drawn on a stretching board or frame, the average size of which is 35 inches long. It is tapered from the bottom which is 5 to 6 inches wide, to 4 inches wide at a distance 4½ inches from the top. The balance of the board should be tapered to a rounded tip. The skin is then drawn gently over the board, fur side in, and stretched lengthwise and tacked at the bottom. From then on it is handled the same as the pelt of an otter or muskrat.

The fur trade knows the pelt of the coypu or swamp beaver as "Nutria" and the fur is judged by the condition, quality, and color of the under fur the same as beaver, otter and muskrat. The color and density of the guard hairs mean little to the fur tradesman for they are removed when the skins are dressed. Nutria pelts are the only skins which are slit open along the back during the processing. The reason is that the fur on the belly and sides is denser and of better quality than on the back.

The under fur should be dark and of a bluish-grey cast. The best pelts are called "blue" by the trade as some natural muskrats are called "black" but these designations should not be taken literally. Reddish or rusty under fur is undesirable. Density is extremely important.

The prevailing prices now being paid for South American nutria pelts taken in the wild are from $8.00 to $9.00 each for top quality skins 30 to 35 inches and longer. Nutria furs trapped in Louisiana during the season 1947 sold for 1.50 to $2.00. The assortment of nutrias trapped in Louisiana varies greatly in size, shape and general appearance. Trappers have not yet learned the proper method of pelting, stretching, and preparing nutria furs for the raw fur market. There are too many small skins measuring 21 inches and less from the eye hole to the bottom of the skin. Such nutria pelts have practically no commercial value and it is unprofitable to pelt and market such skins. The same is true of cut or punctured skins because this damage multiplies many times in processing the pelt.

NUTRIA FLESH AS FOOD

The meat of the nutria when properly prepared, has a pleasing flavor and is excellent eating. Those who are fond of the meat hold it in high esteem, and prefer it to rabbit and hare. They claim nutria is a common article of diet in some districts, just as muskrat is in the United States. When roasted it is similar to suckling pig.

Farmers in South America relish roasted nutria and during the killing season prefer it to other meat. It has also been served in restaurants in Buenos Aires. The average dressed weight is from 8 or 9 pounds. The flesh of the nutria is light pink and on exposure to the air it becomes somewhat darker. It presents a palatable appearance when cooked and does not turn black when prepared by certain methods as in the case of muskrat.

Generally speaking, any areas where muskrats thrive are equally suitable for nutrias. Those having an abundance of water and a natural growth of perennial vegetation are ideal habitats. There are extensive well-watered lands in the United States with dense growth of aquatic vegetation where nutrias would thrive and in a comparatively short time increase the fur production of this country.

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SPECIAL ARTICLE

RIVER DEVELOPMENT PROGRAMS AND THEIR RELATIONSHIP TO FISH AND WILDLIFE RESOURCES

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No impending development holds greater potentialities for affecting fish and wildlife than plans sponsored by the U. S. Army Engineers and the Bureau of Reclamation for manipulating the streams of the Nation. If consummated, these water development progra ns will govern the kind and amount of fish and wildlife over much of our country and will have far-reaching effects on the life and economy of our people. These effects will arise from profound and permanent changes in the environment.

In the past, impoundment programs have generally, if not universally and completely, ignored the fish and wildlife habitat upon which they encroached. The criteria in dam planning and construction have been the number of kilowatts that could be generated, the number of acres irrigated, the greatest benefit to navigation, and maximum protection to property through flood control. All of these purposes are commendable, but they have been achieved in some degree at the expense of other interests, notably fish and wildlife. Conservationists realize that they have paid a high price for not sooner making their voices heard to prevent or mitigate the despoiling of vast areas of valuable habitat. Now, in the face of the most comprehensive impoundment program in history, it is inconceivable that they do less than fight for full consideration of the best interests of fish and wildlife.

It cannot be too strongly emphasized that big dams are permanent and that they result in permanent changes in the environment. Hence, estimates of the fish and wildlife value of a project should be based on full realization that a resource or value lost now is lost for all time. It is for this reason that fish and wildlife interests should be considered during the planning stages of every project, or certainly prior to construction. The past policy of neglect must be abandoned for a broader and more rational view of the totality of our national resources. To do this properly will require, in many cases, the expenditure of additional funds, but the investments will pay dividends throughout the life of the projects.

This philosophy was first recognized by the Congress in the "Coordination" Act of March 10, 1934, a frail instrument with which to accomplish the things that needed to be done. Some improvement in this legislation is reflected in the Flood Control Act of December 22, 1944. A bill, HR 6097, to amend the act of March 10, 1934, was approved by the President, August 14, 1946 (Public Law 732, 79th Congress). This "New Coordination Act" requires that biological resources be given proper consideration in Federal construction, and provides the authority presently

vested in the Fish and Wildlife Service for making studies and recommendations pertaining to such water-development projects. Federal construction agencies are now required to consult with State conservation departments, as well as the Fish and Wildlife Service, prior to construction of water utilization projects.

Under present legislation, therefore, it is the responsibility of the Fish and Wildlife Service to make detailed investigations and reports on the effects of impoundment projects on fish and wildlife, and to submit these reports to the project sponsors, who will consider them as integral parts of project plans. The Service believes that a statement of its policy in making these investigations and reports will be welcomed by the wildlife profession and by conservationists generally.

River Basin Studies Organization

The mandate to study the effects of impoundments, canalization, and other water manipulations on fish and wildlife was received at the height of the personnel shortage, when many technicians qualified for making the required investigations were in the armed forces. The Office of River Basin Studies of the Fish and Wildlife Service was organized in 1945, but through most of the year was forced to operate with such personnel as could be loaned by other divisions of the Service. As a result, progress was unavoidably slow.

The nucleus of an organization was completed late in 1945. The Office of River Basin Studies employs three types of technicians, best described as terrestrial or wildlife biologists, aquatic or fishery biologists, and engineers with biological background. Each group is responsible in both field and office for indicated phases of the work.

The River Basin organization has headquarters in the Central Office of the Fish and Wildlife Service in Washington, D. C., and is headed by the Coordinator. The staff consists of wildlife biologists, fishery biologists, engineers, and an economist. The field staffs are attached to the five Service regions, and to a special region, known as the Missouri River Basin, which is confined to this watershed. This region comprises parts of Service Regions I, II, and III, and its staff has headquarters at Billings, Montana. Approximately seventy biologists are employed in the national organization.

Basin projects, conceived and designed by the sponsor's engineers, are couched in engineers' language, with which biologists usually are unfamiliar. Interpretation by hydraulic engineers, familiar with the biological objectives of the Service, has proved very helpful; and the normal procedure, before field studies are initiated, is to tabulate and condense all pertinent engineering data pertaining to stream flow, project functions, development plans, and proposed methods of operation.

Basis of Evaluation

The agencies concerned with the developments of river basins justify their projects on the basis of the annual monetary value of benefits created as compared with the costs involved. In order that the values associated with fish and wildlife can be made a component part of the cost-benefit ratio, it is necessary for the Service to evaluate these resources in monetary terms.

Establishment of a sound basis for evaluating noncommercial fish and wildlife was a task of great difficulty, for little thought had been given to the monetary aspects of those resources. It was decided that the sportsman's average costs (per pound of fish or per individual game animal) of harvesting them would serve as a basis for primary unit values. Obviously, a unit value determined in this manner would not represent the full value of an individual animal as many indirect and intangible values are not included. (A fully satisfactory procedure has not been developed for measuring indirect and intangible values in monetary terms.) However, when primary unit values are applied to annual take figures, the resultant values are on a comparable basis with the primary values of other resources to be affected by the project.

Since there were almost no accurate records upon which average costs could be based, reliance had to be placed mainly on the opinions of numerous persons qualified to make informed estimates. In spite of some notable differences in opinion, the unit values now in use have had general acceptance by conservationists, and recent studies of sportsman's expenditures are substantiating the original estimates. The values are not applied rigidly, but are subject to modification where special local conditions clearly indicate the need. For commercial forms of fish and for fur animals, the primary sale price realized by the fisherman and trapper is used as a unit value for each species.

The estimated annual value of the fish and wildlife production of a project area is based principally on the annual yield of the fish, fur and game inhabiting the area. This is determined by applying the unit value to the take. Estimation of yields which may be expected after construction of the project is a much more difficult problem. This will be discussed later in this paper.

The Service does not attempt to assign a dollar value to the numerous nongame and noncommercial species, such as small mammals, song birds, amphibians, reptiles, and forage fish. Such forms are a part of the biotic environment, and hence indirectly enter into the value of the others, but they also have esthetic and recreational value. A special problem is presented by vanishing species and by those which are locally too rare to yield an annual harvest to the angler or hunter. It is presently not feasible to establish rules for evaluation of such forms. Each case must be considered separately, in the light of special conditions which surround it. The fact that these values are intangible and not readily amenable to appraisal in monetary terms should not blind us to their importance. The innumerable items which combine to make the "great out-of-doors" have inestimable value. The Service is opposed to indiscriminate diversion of all natural resources to commercial development.

Evaluation of habitat lost through inundation, especially where difficult or impossible to replace, poses another problem of great difficulty. For example, loss through flooding of winter deer habitat in the Plains States, waterfowl nesting grounds in the Dakotas and wintering grounds in the lower Mississippi Valley, or spawning grounds of striped bass in the rivers of the Atlantic seaboard, involves more than

actual commercial value. Except for some possibility of replacement of woody cover, these ranges are seemingly irreplaceable and yet essential to the survival of some of our most valuable fish and game species. The importance of flooding essential habitat is exemplified by the series of impoundments proposed for the Missouri River across almost the full width of North Dakota and South Dakota. Here, under one plan, most of the winter deer cover of a large area would be destroyed, and beaver and upland game losses would be heavy.

In the shelterbelt area of the Great Plains, there is hope for at least partial replacement of cover lost to water programs. Existing evidence is that chances of survival and growth of plantings between the general shelterbelt area and the Rocky Mountains will be progressively poorer east to west, due to lack of sufficient rainfall. There are numerous impoundments located in this region as well as other arid regions. To replace losses of cover in these localities, fish and game interests have authority and justification for requesting impoundments, irrigation, or other means of providing soil moisture sufficient for the growth of the desirable types of woody plants.

Dams on large rivers may seriously reduce the natural range of certain species of fishes. Salmon in the Columbia Basin, paddle-fish and sturgeon along the upper reaches of the Missouri, and shad and striped bass along the Atlantic coast are well-known examples. Conversely, modulation of flow in coastal rivers by impoundments may extend the productive range of estuarine forms such as the blue crab and oyster.

Investigations and Reports

The types of investigations required for water development projects are essentially "before" and "after" evaluations of fish and wildlife resources. "Before" or preproject evaluation involves census or other measurement of fish and game populations and determination of the average annual yield of sport and commercial fishes and of big game, upland game, waterfowl and fur animals. Postproject evaluations require careful application of ecological principles in determining the most likely course of plant and animal succession and, consequently, what species and densities, under a given plan of operation, will occur on the new habitat. It has been necessary to study older reservoirs and irrigated areas, as well as affected streams, for guidance in making estimates of future populations and yields. Most observations of this kind, however, necessarily have been on projects where little attention has been given fish and wildlife in the planning and operation. This circumstance requires careful interpretation of the data obtained before applying it to projects where biological interests are to be considered.

The most reliable evaluations can be obtained through applications of past research conducted by agencies such as the state game departments, fish and game management departments of universities, Federal Aid Research Programs and the Fish and Wildlife Service, Division of Fishery Biology, and the Division of Wildlife Research which includes the Cooperative Wildlife Research Units operating at various schools throughout the country. Their studies, based on long-term research are

necessarily more reliable than those which can be conducted in the comparatively short time allowed for our investigations. The late entrance of the River Basin Study staff in the program, with the resultant limited time to survey projects already authorized, makes application of this research the more important. Unfortunately, sufficient research has not been carried on which can be applied to many of the project areas.

The attitude of the Service toward each project is determined by the "before" and "after" comparisons, reduced to dollars as described, plus a consideration of the prevailing esthetic, essential habitat, and other special values. Projects showing diminished fish and wildlife values subsequent to completion are classed as harmful by the Service; projects showing an increase in these resources as the result of construction and operation under a given plan are classed as beneficial. This policy, it is believed, is well designed to insure proper consideration of fish and wildlife resources in water-development programs.

The various phases of the investigation are conducted by personnel employed for this purpose, often with the helpful assistance of State conservation department personel. Mapping is normally the first field job, and both cover and the cultural features are recorded. All land inundated at maximum flood level, plus a bordering strip is included. Land to be irrigated is likewise covered. The resulting maps offer an excellent field tool to the game technicians, and, since water areas are shown, they are of considerable value to the aquatic biologists. The maps also aid in the preparation of reports and are used freely as illustrations. If aerial photos or suitable maps can be obtained, type lines are drawn in whenever possible before going into the field. It then remains necessary only to check the types and make other needed identifications in the field or laboratory. The last step in the mapping process is determination of acreage of cover types, including water.

The fish and game investigations for each project are made separately, since the procedure, coverage, and rate of travel in these two groups of technicians are different. We rely on, and apply, where possible, past research on populations and yields. Standard census methods are used whenever possible, and considerable information obtained from selected residents is analyzed. The local game warden, sportsmen, conservation groups, and others able to supply pertinent information are consulted.

A weakness of the census techniques as used is that the current population, rather than the average population at a given season, is obtained. Inclusion of information obtained from interviews and other sources with the census data tends to increase accuracy; and as a further refinement, it is planned to census each project area twice: once in the spring and again in the autumn, to obtain breeding and maximum numbers, at least for upland game. Aerial census crews have been organized for winter counts of game, These censuses have shown their value, not only for determining wintering populations of big game, but in some cases, for obtaining information on winter numbers of pheasants, sharp-tailed grouse, prairie chickens, rabbits, and other wildlife.

It is recognized, of course, that dependable evaluations of the wildlife re-

sources on project areas cannot be made without suitable data on populations and yields. Every effort is being made to insure accuracy commensurate with this need.

For most areas, estimates of takes of fur and commercial fish are easier to obtain than similar data for sporting species. State conservation department individual trapper records, local fur buyers and commercial fishermen are good sources of harvest figures, although skill and judgment must be exercised in gathering and interpreting such data. Information on the fishery resource, other than the commercial catch, is usually somewhat more general in nature, since there are few waters on which careful and long-continued creel-census studies have been made. Accordingly, much weight is given to the condition of the habitat, such as seasonal flows, turbidity, oxygen content, salinity, pollution, cover, temperature, bottom and the like. In many areas, it is necessary to give much weight to the testimony of informed local observers.

Supplementary fish and game data are taken from many sources. The various State conservation departments are most valuable in this respect, and in some States it is possible to obtain census and yield figures for the project area, or for similar areas nearby. Where such information covers a period of years, it is obviously more reliable than that for a single year, and in these cases censuses are not always conducted. Records of hunting, fishing and trapping license sales are usually available for the counties involved, and offer some index of the harvest.

State universities and other institutions, especially wildlife, range management, forestry, soils, and agronomy departments, often have information applicable to project areas. Detailed information on special subjects may be obtained from State geological, water, parks, and historical divisions. The value of utilizing these sources, and seeking the cooperation of all agencies having an interest in water projects, is too obvious for comment.

Basin reports are prepared from the information gathered from all sources. Leaders of the game and fish crews responsible for the field investigations prepare the original reports, which are then submitted to the Regional and Central Offices for review and, if necessary, revision. From the Central Office, basin reports in "final rough draft" are submitted to the project sponsor and to the State conservation department involved for study and review.

It may be said that, to date, the points of view of the States and the Service have not been widely different for both have the same objectives with regard to the fish and game resources.

We consider the section on recommendations to be the most important part of our reports. It is here that requirements for the best interests of fish and game are pointed out, and modifications of proposed structures and operation plans are suggested. Recommendations may suggest stable water levels or controlled fluctuations, adequate flows below dams, pollution, erosion and grazing control, cover and food plantings, subimpoundments, refuges and public shooting grounds, and management of the fish and wildlife associated with the projects in accordance with biologically sound principles.

DISCUSSION

It is natural that any activity as complex and as new as evaluation of biological resources to be affected by the nation-wide water utilization program should give rise to numerous questions of policy and economics. Discussion of some of these problems follows.

The value of a reservoir for fish and wildlife, wherein both production and utilization are considered, obviously depends upon many factors. The amount, kind, and season of precipitation, combined with topography, soils and the annual range in temperature, largely predetermines the character of the biological resources it will sustain. In establishing a base for monetary values, physical and ecological factors must be considered jointly with such social realities as human density, character and economic condition of the people, proximity of other recreational areas, and the needs or prior rights of people up- and downstream. It is considered that fully crystallized policy and equitable values will evolve with furthur study and experience.

The value of a reservoir for fish and wildlife depends in a large part upon the way it is constructed and operated. The needs of irrigation, navigation and flood control are often in direct conflict with those of fish, waterfowl, and aquatic fur animals. Good irrigation and flood control result in alternating periods of storage and release of water. Conversely, uniformity in level and flow provide the condition best suited to the majority of aquatic species, including plants. Extreme fluctuations in water level impose severe limitations on the essential life processes of fish and wildlife. In general, the Service does not expect the maintenance of uniform levels in reservoirs; it usually recommends, however, limitation of fluctuations to the narrowest possible range, especially during biologically critical periods, of which spawning may be given as an example. On the other hand, deliberate manipulation of levels in impoundments at the proper seasons may favor both the growth and utilization of waterfowl foods.

Some of the harmful effects of fluctuating levels can be cushioned by allotment of a sufficient volume for dead storage, in addition to the silt-storage allocation. Subimpoundments also serve in this respect, and on many projects may be created by simple dams and spillways on arms of the reservoirs. In general, subimpoundments have relatively uniform levels, and are much smaller and shallower than the main reservoirs. As is well known, such waters are proportionately more productive than large, deep, and widely fluctuating water bodies.

Release of water below dams has a direct relationship to both the reservoir and the stream. Seldom can a stable level in the impoundment and uniform flow below the dam be maintained simultaneously for long periods. Even if fish and wildlife were the only resource to be considered, operational plans for the project would call for a compromise, or the subjugation of one habitat type in the interest of the other. Service policy favors the habitat and resource that will have the greatest over-all value to the people. Thus, if many miles of productive trout or smallmouth bass stream are dependent on ample and relatively uniform flows downstream, it

is usually recommended that release of water sufficient for this purpose be made, even at the expense of stability in the reservoir. On the other hand, reservoirs near large pollution centers and on muddy, warm water streams, especially if of good potential productivity, are favored at the expense of the downstream environment. Where an impoundment is located near the mouth of a stream, the stretch of seriously depleted waterway is not extensive. Where values of the impoundment and stream appear to be approximately equal, a compromise in the operational plan is proposed, resulting in conditions lower than optimum in each environment. Seldom if ever does the Service recommend water releases of such nature as to drain completely either reservoir or stream. The Service, therefore, is generally opposed to water-use practices which result in complete dewatering, even for short periods of time.

Flows of excessive volume and turbulence also are harmful to aquatic life. Large changes in volume of release should be made gradually over a period of several hours or days, in order to avoid this danger. Properly designed stilling basins below the dam tend to minimize turbulence in the river.

The relationship of reservoir age to productivity has been observed and to a limited degree studied by technicians. Practically all writers are in agreement that the initial high productivity of impounded waters is not sustained, and that decline, particularly for sport fishing, is generally inevitable under present methods of control. Management practices effective in maintaining the highest possible initial productivity in large impoundments represent one of the most urgent needs of the nationwide water program.

Differences in the effects of large reservoirs on fish and wildlife in arid and in humid regions should be understood. In the former, water is usually the critical factor in fish and game management, at least from the standpoint of habitat development. Creation of more water area has, therefore, greater opportunity in the west than in the east to improve existing range and create additional habitat for fish, waterfowl, shore birds, aquatic fur animals, and certain species of upland game.

Creation of new irrigated lands in these areas results in much new range of high quality for pheasants, Hungarian partridges, quail and other species of small upland game. In addition, the arid or semi-arid edge of these irrigated lands provide habitat for these same species, and in some instances increases the habitat for such species as the sage grouse. In humid regions impoundments have limited opportunity of improving the present range, or creating new range of real value. Often, the most productive bottomland fields and wooded area are lost through inundation, without creating comparable compensatory range in the vicinity.

A problem of great importance arises out of disturbing the normal water cycle on large flood-plain areas. Ages ago, fish and other wildlife species native to these regions evolved life processes adjusted to periodic and more or less seasonal flooding. For example, numerous fishes, both game and commercial, spawn chiefly in overflow backwaters; millions of waterfowl winter in flooded hardwood bottoms. Profound changes in this environment result when waters

are held back by upstream dams, later to be released and sluiced as rapidly as possible down channels narrowed by levees. Thousands of square miles have thus been "reclaimed" from flood plains and largely cleared for cotton or corn production. Both fish and wildlife habitat of the highest value were lost in the process; and in addition, environmental types essential to the survival of deer, turkeys, waterfowl, game fishing, and the commercial fishing industry have been permanently lost. Leveed streams, subject to violent fluctuations in level, abnormally swift currents, and excessive silt loads are among the poorest of aquatic habitats, whether for fish, waterfowl, or fur animals. It is conceivable that overflow backwaters in the Mississippi Valley, valleys throughout the Gulf and South Atlantic States and elsewhere, can be dried up by a sufficiently great dam and levee system.

The Service, in its basin reports, takes a strong position against pollution. In all reports covering projects where pollution is dangerous to fish and wildlife resources, it is recommended that the pollution be eliminated, abated, or otherwise remedied, and that no new sources of pollution be established.

Damming of a large number of streams and the resultant creation of large artificial lakes will have certain obvious effects on fish and wildlife and on the recreational and commercial opportunities associated with these resources. It presently appears that the total amount of upland-game habitat will be decreased, and in some regions the decrease promises to be critical. In irrigated areas, habitat for certain upland game will be greatly increased in acreage. Total waterfowl range, particularly rest grounds, will be increased. However, due to fluctuating water-levels in most of the reservoirs, the net increase in waterfowl feeding grounds will be small unless special means are implemented to modify normal conditions. Fluctuating levels will also weigh against muskrats, which might otherwise find in the impoundments much suitable range. The total mileage of streams will be reduced by inundation, but because of clearer water and more uniform flow, many will offer improved environment for fish and game below the dams. Within the range of the various species in the plains and plateau states, irrigation of new land will create vast new habitat for the pheasants, Hungarian partridge, and other species of small upland game.

It is too early to predict the effect of the numerous water programs on fish and wildlife as a whole, even if a large number, or all, of the projects are operated as favorably as possible to biological interests. It is certain, however, that as a whole they will not be favorable unless these interests are given every reasonable consideration.

The means are at hand to give this consideration in the provisions of the Flood Control Act of December 22, 1944, and the "New Coordination Act." The challenge therefore lies squarely at the door of the biologists accurately to determine the effects of river basin developments on our fish and wildlife resources. It is of equal importance to find practical biological practices to reduce unnecessary losses to these resources. Perhaps the greatest challenge is the application of sound biological practices on these developments to increase the resources for which we are responsible.

BRIEFER ARTICLES

THE OCCURRENCE OF THE GRANULAR TAPE-WORM *ECHINOCOCCUS GRANULOSUS* IN WILD GAME IN NORTH AMERICA

The occurrence of hydatid disease in man in the United States and in Canada was reviewed in detail by Magath in 1937. At that time he showed that there was no evidence of the classic relationship between dogs and domestic sheep in the transmission of this parasitic disease in North America. He called attention instead to Riley's (1933) report of a wild cycle in Minnesota, where wolves were serving as the terminal host for *Echinococcus granulosus* and moose the intermediate host for the hydatid stage, with the suggestion that the wild cycle might be the important one on his continent.

Before and since the publication of this paper additional parasitological examinations of game animals have brought to light other hosts and other regions in which game animals are now known to harbor this parasite.

Fenstermacher (1934) reporting upon the examination of 19 moose (*Alces americana*) in Minnesota, found that eight of them bore *Echinococcus* cysts in the lungs. Two of three timber wolves examined were heavily infested with the adult stage of this cestode. Later, during the examination of 4 more moose from the same state another hydatid infestation was discovered (Fenstermacher, 1937).

Law and Kennedy in 1933 reported upon a case of hydatid disease in a captive moose in Ontario.

Riley (1939) and later Olsen and Fenstermacher (1943) reported the presence of hydatid cysts in the lungs of the white-tailed deer, *Odocoileus virginianus borealis* in Minnesota. The last authors state that only two cases were encountered in an examination of 95 deer, an incidence of just over 2 per cent.

During the course of wildlife studies upon Vancouver Island, B. C. and in Banff and Jasper National Parks, Alberta, the writer has discovered two additional loci of wild infestations.

A buck Columbian black-tailed deer (*Odocoileus hemionus columbianus*) taken at Crofton, V. I., B. C., on October 8, 1938, bore two hydatid cysts in its lungs (Cowan, 1946). The mountain lion (*Felis concolor*) was the only wild deer predator upon the deer range at Crofton and it was uncommon. On the other hand, the infested deer was feeding upon an area pastured by domestic sheep and regularly travelled by domestic dogs. Several dogs had become feral in the area, killing domestic sheep and deer and it seems probable that these dogs were serving as the ultimate host of the parasite. This was the only case encountered in an examination of 65 wild deer from Vancouver Island and from the British Columbian mainland near Vancouver, B. C.

In Jasper and Banff National Parks, Alberta, I have found a wild cycle involving elk (*Cervus canadensis nelsoni*) and mule deer (*Odocoileus hemionus hemionus* as intermediate hosts and the timber wolf *Canis lupus occidentalis* as one of the terminal hosts.

Hydatid cysts were first found in elk in Jasper in June 1944 when it was noticed that certain cow elk were in poor condition and manifest a delayed moult. Three were shot for examination and two of them bore cysts in their lungs.

During the annual reduction of the Banff elk herd in the winter of 1944–45 cystic lungs were taken from three elk and sent to this laboratory. On the basis of this sample of 200 elk the incidence of hydatid disease in Banff elk in 1944 was at least 1.5 per cent. A more careful examination was made of the 352 elk slaughtered there in the winter of 1945–46 and records kept by special warden H. U. Green reveal an incidence of 6.5 per cent in that sample.

The elk slaughtered in Jasper Park during these two winters were not subjected to careful examination but reports of the wardens who did the butchering indicate a significantly higher incidence of infestation there than in Banff.

One lung sent to the laboratory from

Jasper, on January 21, 1946, was almost completely replaced by the great mass of cysts it contained.

On May 2, 1945, at Jasper, the writer slaughtered an ailing, senile, doe mule deer and removed six hydatid cysts from its lungs. This is apparently the only reported instance of the cysts of *Echinococcus* in mule deer.

Mountain lions (*Felis concolor*), timber wolves and coyotes (*Canis latrans*) are the wild predators upon elk and mule deer in the Athabaska Valley of Jasper National Park. Between 1943 and 1945 one lion, one wolf and six coyotes from this area were examined for internal parasites. The wolf bore a moderate infestation of adult *Echinococcus*, the other species were negative.

The infested area in the Bow Valley of Banff Park was without a wolf population until 1945 when one animal paid a brief visit to the region. One or two wolves were present in the valley during the winter of 1945–46 but certainly wolves have not been involved in the establishment of hydatid disease in this elk herd, for the disease was well established prior to the appearance of wolves.

Mountain lions occur in small numbers and may attack elk but the only wild predator at all numerous is the coyote. To date just three of these have been examined and all have been negative.

The occurrences of *Echinococcus* recorded here lend further weight to the suggestion that in North America the wild cycle, involving native canids as the terminal host, is the important one, although there is one instance in which the domestic dog, probably feral, was almost certainly the terminal host. The evidence from the Banff area strongly suggests that the coyote was the terminal host during the establishment of the parasite in the elk herd there.

The infested areas in Banff and Jasper Parks are the main valleys, traversed by major highways and subjected to the most intensive tourist use. These infestations would seem to be potentially more dangerous as sources of human infestation than any other wild cycle so far discovered in North America but even here the actual danger of humans acquiring infestation is probably small.

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SOME OBSERVATIONS ON DEN TREES IN THE MISSOURI OZARKS[1]

A wolf tree, by definition (Forestry Terminology 1944), is "a tree occupying more space than its silvicultural value warrants, curtailing better neighbors." The same glossary defines a den tree as a "hollow tree used as a home by a mammal."

Foresters interested in producing trees only are likely to desire the complete elimination of wolf trees and den trees because they are returning only a low value in saw logs or stave bolts. The wildland manager, on the other hand, interested in both timber and wildlife, must take these trees into consideration as requisite toward a greater production of all wildland crops.

The U. S. Forest Service (1940) recognizes the importance of den trees in the statement, "Where needed for dens, these trees are not to be cut in any stand improvement or release job."

How many den trees are needed for rearing a family of squirrels? Terrill and Crawford (1946) state that each pair of squirrels needs three dens, one for the female, a second for the male while the young are in the nest, and a third for the young squirrels after they have been weaned and evicted from the home den. Brown and Yeager (1945) suggest that "four or five usable cavities per acre are probably ample for any permanent squirrel population."

A survey of den trees available to squirrels was made on Deer Run State Forest during January, February, and March, 1939. A five per cent cruise was made of 7,200 acres. Strips one chain wide (66 feet) were run north and south four times through each section. A crew of five CCC enrollees and a recorder made up the field crew.

All live trees 12 inches D. B. H. and over containing cavities or hollows were tallied by species and diameter classes. Trees which had no visible holes either in the limbs or trunks were tallied as sound, even though some seemed hollow when hit with an axe. Trees with visible cavities were divided into two classes: those having hollows in the trunks at the ground level, and those with holes either in limbs or in the trunks above the ground level. The former were considered as home dens and the latter as escape dens or places to hide.

The timber on Deer Run State Forest is typical of the oak-hickory and oak-pine forests of the east central Missouri Ozarks. The oak-hickory association is the most common, as well as the most complex association of the Ozark ridges and uplands. Shortleaf pine may be associated with black oak, post oak, white oak, scarlet oak, or blackjack oak or with Ozark hickory. The merchantable stand on Deer Run State Forest is composed of white oak, 28 per cent by occurrence; scarlet oak 25 per cent; post oak 16 per cent; black oak 14 per cent; hickory 10 per cent; black gum 5 per cent; and short-leaf pine 4 per cent. Blackjack oak, hard maple, black walnut, white ash, and sycamore were also tallied, but occurred so sparsely in the stand they were not included in the compilation.

A scattering of old cull trees, largely white, black, and scarlet oaks remaining from a previous timber cutting 30 to 35 years ago, make up the bulk of the trees large enough for raccoon or opossum dens.

At the time the survey was made timber stand improvement was being done by the Civilian Conservation Corps, and a number of den trees were subsequently removed. In 1941 fire destroyed several sections of this timber, so the follow-up work planned was never carried out.

The following table summarizes the data on the seven species of trees comprising the stand of merchantable timber. There were 2,456 trees tallied, of which only 10 per cent contained dens.

Trees showing no holes in either limbs or trunks were considered sound. Many of these apparently sound trees were hollow, and thus probably should be considered potential den trees.

The seven tree species showed a wide variation in the kinds of dens.

[1] A contribution from the Missouri Cooperative Wildlife Research Unit, Missouri Conservation Commission, University of Missouri, Wildlife Management Institute, and U. S. Fish and Wildlife Service cooperating.

TABLE 1.—RELATION OF DEN TREES TO TOTAL STAND, DEER RUN STATE FOREST, MISSOURI

Species	No. den trees	No. den trees per acre	No. sound trees	No. sound trees per acre	Total no. trees per acre	Ratio den to sound trees per acre
White oak *Quercus alba*	77	0.21	606	1.69	1.90	1:7
Scarlet oak *Quercus coccinea*	46	0.13	561	1.56	1.69	1:12
Post oak *Quercus stellata*	39	0.11	396	1.00	1.11	1:10
Black oak *Quercus velutina*	28	0.08	307	0.85	0.93	1:3
Black gum *Nyssa sylvatica*	38	0.08	92	0.26	0.34	1:12
Hickory *Carya* spp.	18	0.05	220	0.61	0.66	1:11
Shortleaf pine *Pinus echinata*	7	0.01	79	0.22	0.23	1:9.8
	245	0.67	2,223	6.18	6.85	1:9.8

The den trees as a whole averaged 3 to 5 inches larger in diameter than the sound trees. The ratio of den trees to sound trees varied from 1:3 in black oak to 1:12 in scarlet oak. Scarlet oak showed the least amount of defect as revealed by the presence of limb or trunk dens. Only 7.6 per cent of all scarlet oaks tallied revealed dens, while 9.7 per cent of white oak and 8.4 per cent of the black oaks contained dens. Approximately a fourth of all black gum trees revealed dens. Black gum was found in only 5 per cent of the stand, but is not so important as pine as a den tree species because three-fourths of dens were only escape holes at the ground level. Pine, however, showed 100 per cent holes high up on the main stem.

TABLE 2.—RELATIONSHIP BETWEEN TREE SPECIES AND TYPE OF DEN

Species	Per cent home dens	Per cent escape dens
White oak	*41*	*59*
Scarlet oak	*91*	*9*
Post oak	*68*	*32*
Black oak	*86*	*14*
Black gum	*23*	*77*
Hickory	*28*	*72*
Shortleaf pine	*100*	*0*
Average	*62*	*38*

A high percentage of these holes are the result of pileated woodpecker activity.

The type of timber stands with scarcely 7 trees to the acre 12 inches and over is typical of thousands of acres in the Missouri Ozarks, now in private ownership. A recent survey of the growing stock on 175,000 acres of the Winona District of the Clark National Forest (Sluzalis, 1947) showed an average of 13 (±17 per cent) trees per acre 12 inches D. B. H. and over. The 20 per cent cull recorded in this timber survey in all probability means at least two den trees per acre. The mature oak-hickory association of the Ozarks is an open forest and, therefore, is not likely to have an overabundance of den trees even under good management.

The heavy cutting of Missouri's privately owned oak forests during the war years has rendered thousands of acres uninhabitable for squirrels during the breeding season. It will take two to three decades to re-establish year-round squirrel habitat in many of these cut-over areas.

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—PAUL D. DALKE,
Missouri Cooperative Wildlife Unit, Columbia, Missouri.

DEER SELECT MOST NUTRITIOUS FORAGES[1]

In the process of a survey of the composition of various forages as influenced by different soils and fertilizer treatments, our attention was called to the fact that on the Stanley Fidley farm in Centre County, Pennsylvania, white-tailed deer (intermixture of *Odocoileus virginianus virginianus* and *O. v. borealis*) consistently grazed on the young wheat plants which grew in a certain elevated portion of the field. It was necessary for the deer to travel through several rods of the open wheat field to reach the area where they chose to eat. A similar observation was made in the same general area in regard to a field of clover.

These observations raised the question of whether there might be a significant difference in composition of the wheat and clover from the areas preferred as compared to those ignored by the deer. Samples of wheat and clover were gathered by Dr. Logan J. Bennett, Professor of Wildlife Management and Professor Howard Higbee of the Department of Agronomy, on May 18, 1943. In addition to these samples, wheat kernels were also obtained late in July of the same year from the areas of interest. It was thought that factors of heredity and reproduction would tend toward a constant composition of the seeds of a given species even though differences were found in the composition of the young plants.

Feed and mineral analyses, made by the Department of Animal Nutrition, are presented in tabular form.

TABLE 1.—COMPARISON OF THE COMPOSITION OF WHEAT AND CLOVER EATEN BY DEER WITH THAT IGNORED BY THEM (DRY MATTER BASIS)

	Energy	Crude protein	Crude fiber	Ether extract	Ash	Ca	P	Mg	K
	Cal. per gm.	%	%	%	%	%	%	%	%
Wheat									
Grazed	4539	16.75	24.49	5.73	8.78	.43	.48	.16	2.63
Not Grazed	4446	16.69	25.33	5.22	8.65	.29	.37	.14	3.15
Difference	93	.06	−.84	.51	.13	.14	.11	.02	−.52
% Increase*	2.1	.4	−3.3	9.8	1.5	48.3	29.7	14.3	−16.5
Clover									
Grazed	4582	30.38	16.25	4.70	8.90	1.73	.44	.27	2.05
Not Grazed	4555	26.13	16.14	4.14	9.33	1.36	.32	.37	2.63
Difference	27	4.25	.11	.56	−.43	.37	.12	−.10	−.58
% Increase*	.6	16.2	.7	13.5	−4.6	27.2	37.5	−27.0	−22.1
Wheat Kernels									
Grazed	4539	14.13	2.86	2.05	2.34	.08	.57	.19	.50
Not Grazed	4576	14.44	3.02	2.10	2.46	.07	.57	.21	.49
Difference	−37	−.31	−.16	−.05	−.12	−.01	.00	−.02	.01

* Percentage increase in the grazed over the ungrazed forage.

[1] Authorized for publication on June 20, 1947 as paper no. 1378 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

The difference in composition of the mature grain from the two areas is negligible. Regarding the wheat and clover harvested at the time when the deer were manifesting their preferences, however, it is obvious that the superior forage was chosen in both cases. In the case of the wheat, the area grazed produced forage of higher nutritive value from the standpoint of each ingredient determined except potassium which may safely be assumed to be above the optimum in both cases. Some of the differences are too small to appear significant while the larger ones may well be considered along with corresponding results on the clover.

Although the clover eaten by the deer contained about 14 per cent more protein than did the clover rejected by them (30.4 per cent *vs.* 26.1 per cent), the two wheat samples were practically identical in protein content. It is unlikely that protein was a factor in the selection of clover since the sample poorest in this nutrient contained an adequate amount.

It seems justifiable to omit consideration of energy, crude fiber, ash, and magnesium as significant factors. In the case of both the wheat and the clover the energy values of the chosen and of the ignored forages were approximately equal. The crude fiber, ash, and magnesium content of the wheat and clover apparently played no important part since these ingredients were inconsistently high or low in the selected feeds.

Eliminating consideration of the differences of the ingredients which are inconsistent in the case of the two forages, as well as the very small positive concordant ones, it is evident that the outstanding features of the feeds chosen by the deer are the greater amounts of calcium, phosphorus, and ether extract contained in them. It is of course, impossible to state that any one of these ingredients or that the combination of all three was actually responsible for the choice. It is interesting to note, however, that the deer, entirely free to choose, ate those feeds which gave them about 12 per cent more ether extract, 38 per cent more calcium, and 34 per cent more phosphorus.—R. W. SWIFT, *The Pennsylvania State College, State College, Pennsylvania.*

AN ELECTRIC FENCE FOR USE IN CHECKING PORCUPINE AND OTHER MAMMALIAN CROP DEPREDATIONS[1]

Time and again, single and double strand electric fences used in a variety of arrangements have failed to impede the inroads of porcupines, raccoons, fox or skunk on cornfields and gardens. In the case of porcupines, should they nose under the lower wire the dense quill pelage serves as a perfect insulator and no electric shock is experienced. There is a practical limit on how low the "charged" wire may be on the fence, for vegetation touching this wire may short the fence, thereby making it inoperative. Furthermore, porcupines, are stubborn animals and if the way seems relatively unobstructed they will scramble over an electric wire despite the attending shock.

To deter porcupines, poultry or hog netting of a minimum height of 18 inches must be employed. Posts should be set at 20–25 foot intervals and the netting tightly stretched. In addition, wooden stiffeners should be laced into the netting (between posts) to prevent any sagging under the animal's weight. The bottom of this netting must conform closely to the ground contour. Porcupines do not normally attempt to

[1] Since the completion of this research and preparation of the manuscript, two other accounts of the successful use of a similar fence to repel raccoon and skunk have come to the author's attention. One is an unpublished account by F. M. Uhler of the Patuxent Wildlife Refuge of an electric fence to protect cornfields. The other is an article entitled "Electric Fence for Keeping Small Animals out of Peanut Plots," by Henry C. Harris and Fred Clark, in the Journal of the American Society of Agronomy, Vol. 38, No. 12, December, 1946.

burrow, but if the fence is to be used to exclude raccoon, fox and skunk as well, then it will be necessary to use a wider netting and trench it into the soil about six inches.

The electric charge is carried by either a No. 12 or No. 14 smooth wire attached by porcelain insulators to the fence at a level with the top of the netting. The smooth wire must never be more than 1½ inches from the netting (top side). This is very important. If the porcupine can sag the netting enough to get its head between the charged wire and the netting, it will squeeze through without harm. To hold the charged wire and netting in correct relative position it will be necessary to devise a number of insulating links. In the capturing and marking of porcupines on the Mesa Verde National Park, Colorado, we used small rectangles of lucite plastic drilled at each end for this purpose. One end of these links is threaded on the smooth wire and the other end clipped to the top of the fence netting by use of the smallest size pig ring.

The positive (hot) current is carried only by the smooth wire—the negative current by both netting and ground, so that dry soil condition does not lessen the electric fence efficiency. Electric shock results from closing the circuit between the ground and the smooth wire or by contacting both wire netting and smooth wire, as would result when the animal attempts to climb over the fence. In operating, (1) patrol the fence at regular intervals to remove weeds and vegetation that may have come in contact with the charged wire; (2) shut off the current during rains; and (3) if dry-cell batteries are used for power, they must be protected from freezing.

The above electric fence may be adapted to a number of situations. The fence may completely encircle the area to be protected or merely be a dividing fence between the native woodlands and the crop. In the latter situation, traps may be set at the ends of the fence and the offending mammals removed. An electric fence also makes an excellent holding pen for experimental wildlife work.

The low fence described above is advantageous for it eliminates the necessity of gates (except where teams and power equipment are used in an encircled field). However, where the entrance of machinery is not a problem, the writer would suggest that the poultry netting be continued six inches above the charged wire (total height 24 inches) to form an additional obstruction. The charged wire must never be more than 1½ inches from the netting on the outside of the fence, the distance being maintained by insulators and links.

A porcupine is a stubborn and determined animal. Its first reaction to the fence is an attempt to walk through it—a performance oft repeated. Eventually it occurs to the porcupine that the obstruction can be climbed, about which task it proceeds with caution. More often than not, it noses the charged wire before laying a paw upon it. When the shock hits, the porcupine drops back to the ground, whirls with tail toward the fence and all quills raised in a defensive attitude. There being no follow-up to the attack, it slowly faces about and puzzles over the matter. The porcupine may even attempt a second climb in a matter of minutes, only to repeat the entire defensive performance. It will then move along the fence and after a time make a third try at a new place. This time it eyes the charged wire and keeps its nose at a safe distance; instead a paw is reached up to take hold of the wire. You know the result. I have observed a porcupine make five such attempts to climb an electric fence in two hours—stubborn, and maybe a little slow mentally.—DONALD A. SPENCER, *U. S. Fish and Wildlife Service, Wildlife Research Laboratory, Denver, Colorado.*

REVIEWS

Outline of the Principles of Wildlife Management. By Warren Chase and Elizabeth B. Beard. Ann Arbor, The Overbeck Co. 61 pp. 1947. $1.75, and *Outline of Waterfowl Management,* same authors and publisher. 28 pp. 1947. $1.25.

These manuals, prepared at the University of Michigan, are printed by the offset process and bound in paper. Those teaching a course dealing with wildlife management, ecology, or animal populations should have access to these teaching aids. The outline organizes the subject matter into units in order to stress principles. Five to ten questions follow the outline of each unit which is concluded by basic and general references. These up-to-date references constitute the largest part of the manual and should be valuable to all wildlife workers as well as to teachers.—HURST H. SHOEMAKER.

The Ruffed Grouse, Its Life Story, Ecology and Management. By Frank C. Edminster. New York, The Macmillan Company. xxvi+385 pp., 56 pls., 17 figs. 1947. $5.00.

Students and workers in the wildlife field will find much of interest in this book as there has long been a need for a volume such as this to assemble between the covers of one book the facts gleaned by the numerous ruffed grouse investigations of the past three decades; facts which too long have lain hidden within the pages of a host of publications, many of which are not readily available to the public.

More than seven years of work with the New York Grouse Investigation and an additional eight years of study of wildlife in the Northeast with the U. S. Soil Conservation Service eminently qualify the author to discuss his subject. Moreover, he has through correspondence and personal contact obtained some unpublished findings from other investigators who have studied the ruffed grouse in the East and Mid-west.

In the author's words, "It is not intended that this book be an exhaustive treatise on all phases of study of this species. Rather it is hoped to cover the high spots of the life history, the ecology, and management of the ruffed grouse in a manner interesting to the sportsman, the nature lover and the lay reader and at the same time be accurate and adequately documented for the technical man in the field of wildlife management." Nevertheless, he has covered most of the known facts about the bird in a rather comprehensive manner.

Although the style and language are perhaps too difficult for easy reading by the general public, the book is indeed well documented and contains an extensive bibliography at the end of each chapter. The latest literature cited is dated 1944. Unfortunately, there are a few errors in scientific names of birds and in initials and spelling of some authors' names. Also, in a few cases, anonymous papers have been accredited to the author of the publication preceding them in the list.

Fifty-six pages of photographs depicting various phases of ruffed grouse life history, food habits and cover, greatly augment the clarity of the text. In addition to the plates, there are eleven pen and ink drawings by William Montagna of Cornell University, at the chapter endings, and seventeen diagrams, charts and tables.

The book is divided into three sections, the first being concerned with the life history of the grouse, including descriptions of the bird, its history and its yearly cycle of activities. A section on the ecology of the grouse in the Northeast follows and includes food, water and cover requirements, effects of weather, predator relationships, diseases and parasites, productivity and population mechanics. The final section describes management practices and comprises the use of restrictive legislation, refuges and manipulation of cover. Considerable space is given to methods of propagating food and cover plants.

Since this is the first comprehensive resumé of the existing data on the ruffed grouse to be written by a qualified biologist, it meets a long felt need and deserves a place on a wildlife manager's bookshelf.—WARD DEAN TANNER AND GLENN L. BOWERS.

NEWS NOTES

The nominating committee of the Wildlife Society, composed of Leo K. Couch, John R. Langenbach, Lloyd W. Swift, Clarence M. Tarzwell, and Chairman Rudolf Bennitt report the following nominations for officers of the Society:

PRESIDENT

Dr. Warren W. Chase, School of Forestry and Conservation, University of Michigan, Ann Arbor, Michigan.

Dr. Tracy I. Storer, Division of Zoology, University of California, Davis, California.

VICE-PRESIDENT

Dr. Ian McT. Cowan, Department of Zoology, University of British Columbia, Vancouver, B. C.

Mr. Frank C. Edminster, U. S. Soil Conservation Service, Upper Darby, Pennsylvania.

TREASURER

Dr. Paul D. Dalke, Idaho Cooperative Wildlife Unit, University of Idaho, Moscow, Idaho.

Dr. Neil W. Hosley, U. S. Fish and Wildlife Service, Washington D. C.

Dr. Bennitt points out that the treasurer is elected for a two-year term but, in the event that the Society appoints a full-time executive secretary, the person elected treasurer will serve only until such an executive secretary assumes his duties.

On October 4 and 5, 1947, The Atlantic Fisheries Biologists held their fall meeting at the Atlantic Biological Station, St. Andrews, New Brunswick. The purpose of the Society is to promote the interchange of ideas on fisheries research through informal discussion.

The officers of the Society for 1947 were Dr. J. C. Medcof, President and Dr. M. W. Smith, Secretary-Treasurer, both of the Fisheries Research Board of Canada, Atlantic Biological Station, St. Andrews, N. B. The officers elected for 1948 are Mr. C. C. Taylor, President, and Mr. F. T. Baird, Jr., Secretary-Treasurer, both of the Maine Department of Sea and Shore Fisheries, Augusta, Maine.

Now, two years after the war, conditions in much of Europe are worse than they have ever been during modern times. Not since the Middle Ages have people from Central Europe been subjected to such widespread misery and to such a rapidly mounting death rate.

One wildlifer writes: "We seek in the woods for food that in former times was scarcely thought fit for cattle: weeds and acorns, but these are small and dry. We have not had eggs since Easter." Another writes: "Would it be possible for you to send some food, especially fat of any sort, for my children." Another: "Could you send a pair of used shoes, my last shoes have given out." Some take turns at *the* pair of shoes, one wearing them to work while the other stays at home.

Many of us have boots or shoes and warm clothing in our closets which we can spare.

Food is even more important than clothing. In parts of Central Europe this year's drought was worse than any in 72 years. It was a catastrophe. The potatoes, usually a staple, "were no larger than pigeon's eggs and the fruit fell from the trees unripe. . . . We fear the winter."

How to send food. The following Societies now have Relief Committees:

Foresters—Tom Gill, chmn., 1214 Sixteenth St., Washington 6, D.C.

Ichthyologists and Herpetologists—M. Graham Netting, chmn., Carnegie Museum, Pittsburgh 13, Pa.

Aquatic Biologists—Arthur D. Hasler, chmn., Zoological Laboratory, University of Wisconsin, Madison 6, Wis.

Mammalogists—Caroline Sheldon Murdock, chmn., Washington Court House, Ohio.

Ornithologists—F. N. Hamerstrom, Jr., chmn., Pinckney, Mich.

Either send a check to one of the above, who will be glad to send a CARE package in your name, or ask him for the name of a European to whom you can send personal packages of food or clothing. A little extra food from this country goes a long way. It is saved and eaten little by little. A CARE package a month is an enormous help to a family; the cost is $10. Contributions of *any* size are welcome.

Indiana was host to the Ninth Midwest Wildlife Conference held at Lafayette, December 9–11, sponsored jointly by Purdue University and the Department of Conservation. The committee on arrangements included: W. B. Barnes, Department of Conservation, C. M. Kirkpatrick, Purdue University, and W. E. Ricker, Indiana University.

Headquarters were in the Purdue Memorial Union Building. The opening general session was comprised of addresses by Director Albert M. Day, Washington, D. C.; Dr. John Van Oosten, Michigan; Dr. Rudolf Bennitt, Missouri; Dr. Gustav A. Swanson, Washington, D. C.; Dr. Arthur D. Hasler, Wisconsin; Dr. Harlow B. Mills, Illinois. Eight special sessions were devoted to reports on game and fish management research; conservation education; and river basin development. During one evening, the Purdue Wildlife Laboratories were open for inspection following which informal group discussions were conducted for those conferees interested in pheasant, quail, and other farm game; deer; grouse; furbearers; waterfowl and marsh management; college training; and methods of estimating abundance and mortality of fish populations.

The banquet featured an address by H. Albert Hochbaum, Delta Waterfowl Research Station, whose topic was, "The Management of Man," an analysis of the behavior of wildlife managers themselves relative to their management of waterfowl. Mr. and Mrs. Cleveland P. Grant presented one of their excellent films, "Rams of the Rimrocks." Mr. Kenneth A. Reid, Executive Director, Izaak Walton League of America, acted as toastmaster.

When tallied by states, the registered attendance of 236 gives Illinois, 49; Indiana, 39; Iowa, 6; Kansas, 3; Kentucky, 3; Michigan, 29; Minnesota, 12; Missouri, 29; Nebraska, 5; North Dakota, 3; Ohio, 25; South Dakota, 5; Tennessee, 1; Wisconsin, 19; Washington, D. C., 7; Canada, 1. Considering Purdue students and staff and others known to have attended without registering, it is believed that a total attendance of 325 would be approximate.

Michigan was chosen as host of the 1948 conference with Harry D. Ruhl appointed to initiate arrangements.

OBITUARIES

WILLIAM CARL GOWER

1911–1945

William Carl Gower, biologist with the Game Division, Michigan Department of Conservation, died February 5, 1945, at Lansing, Michigan. Burial was at his old home in Carbondale, Illinois. His death was presumably due to septicemic tularemia contracted from a cottontail rabbit in the course of an autopsy.

Dr. Gower was born May 13, 1911, at Carbondale, Illinois. He attended elementary and high schools there. From 1929 to 1932 he studied at Southern Illinois Teachers College, also at Carbondale, receiving a Bachelor's degree in Education. In 1933 he became a graduate assistant in Zoology at Louisiana State University, receiving a Master's degree in Zoology in 1934. The scholastic year of 1934–35 was spent as a graduate assistant in Zoology at the University of Illinois.

His residence in Michigan began in 1935 when he came to the W. K. Kellogg Bird Sanctuary of Michigan State College as an assistant to Dr. Miles D. Pirnie, Director. His work there was centered on the trematode parasites of ducks. He received his Ph.D. in 1937 from Michigan State College.

His association with the Michigan Department of Conservation began August 1, 1937. He worked until 1939 in the Game Division Laboratory on the Michigan State College campus. From 1939 to 1942 he was in charge of the Game Division's Swan Creek Wildlife Experiment Station near Allegan, Michigan. He returned to Lansing in 1942 to serve as biologist at the Game Division central office until his tragic death.

Most of his earlier publications were concerned with the trematode parasites of ducks, although he had other interests as well and published papers on other zoological subjects. Perhaps his best known paper concerned the use of the bursa of Fabricius as an age indicator in game birds.

His interests are indicated by the scientific societies to which he belonged, which were: American Society of Mammalogists, Society of Parasitologists, American Microscopical Society, and the Wildlife Society (from 1940).

Gower was an outdoors man in addition to being an accomplished laboratory technician. He was an expert photographer, a good archer, a bird dog lover, and an enthusiastic hunter. He could talk the language of the people with whom those directly concerned with game management problems have to deal so much—the farmer and the hunter. He was admirably fitted for his position with a public conservation agency. His family, associates, and friends feel his untimely loss keenly. There can be no adequate replacement.

He married Janice Lockie of Carterville, Illinois, in 1933. He is survived by his wife and their two children, Carol Jan and Gale Linda Gower.—S. C. Whitlock.

GORDON THOMAS WOODS

1916–1947

Gordon Thomas Woods, a member of The Wildlife Society from 1943, died at his home in Newington, Connecticut, March 3, 1947. He was born May 25, 1916 at Hartford, Connecticut. During the intervening years he graduated from the New Britain High School in Connecticut; the Stockbridge School of Agriculture at the University of Massachusetts, majoring in Wildlife Management; and the School of Forestry and Conservation of the University of Michigan with a Bachelor of Science degree.

Gordon was an ardent lover of nature as well as a keen student of natural science. His interest in both animals and plants was broad and genuine and as a student he was

untiring. During the summer of 1941 and 1942 he worked at the University of Massachusetts compiling a bibliography of the literature in the wildlife field. During the same period he also engaged in biological projects, including study of the incubation of snapping turtle eggs, the growth of chimney swifts, and the development of sparrow hawks. His bibliographical work as well as his field notes were precise and accurate and he always showed eagerness and enthusiasm for everything that pertained to wildlife. During his stay at the University of Michigan, Gordon cared for the animals at the University Museum and became much interested in the wolverine. He wrote two articles on this animal both of which are noted in the subjoined list of references. Gordon developed color photography as a hobby during the years he was in college and took many kodachrome pictures of both plants and animals, some of which he sold to commercial slide companies. After graduation, he worked for both the Massachusetts and the Connecticut Conservation departments on Pittman-Robertson projects.

During the last year before his death, Gordon was unable to use his eyes on close work, was confined to his home, and was unable to pursue studies in his chosen field. He retained his interest in wildlife to the last and with his mother on the day before his death discussed various activities which he planned for the coming summer season. The cause of death was diabetes and complications resulting therefrom. He was buried at Newbury, Vermont.

The following is a list of his publications:

1940. New England Hurricane Benefits Wildlife, American Forests, **46**(9), September, pp. 402–404, 424.

1940. Chimney Swifts Destroy Many Insects, Bird-Banding, **11**(4), October, pp. 173–174.

1941. Early Summer Food Habits of Gray Squirrels, Journal of Mammalogy, **22**(3), August, pp. 321–322.

1944. Longevity of Captive Wolverines, American Midland Naturalist, **31**(2), March, p. 505.

1944. Black Snake Attacks a Boy, Copeia, No. 4, December, p. 257.

1945. Rate of Travel of the Wood Turtle, Copeia, No. 1, March, p. 49.

1946. Filing Natural History Slides, Journal of Wildlife Management, **10**(1), January, pp. 63–65.

1946. The Wolverine, Nature Magazine, **39**(8), October, pp. 426–428, 444.—R. E. TRIPPENSEE.